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An Ephemeral Type of Industrial Land Occupance

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THE OIL FIELDS OF THE LOS ANGELES BASIN

The composite surface features of oil field areas and the many derangements in land utilization resulting from the introduction of transitory petroleum-extracting activities into established rural and urban districts afford little-tried opportunities for detailed geographical interpretation.

It is proposed here to discuss the oil fields of the Los Angeles Basin in southern California from the viewpoint of land occupance. It will be a particular object to describe and interpret the forms of surface land utilization characteristic in oil fields of varied physical and economic types and expressive of different stages of development. The highly unstable conditions of land utilization arising from the competition of the oil industry with former land uses will be demonstrated. The brief interval of time required for the completion of the cycle of land occupance and abandonment by the oil industry and the return of somewhat permanent land uses will be shown.

The Los Angeles Basin (Fig. 1) is especially suitable for such an investigation because it has within a relatively compact area a wide variety of field types not only in respect to physical and cultural settings but also in stages of exploitative development. Twenty-five separate oil fields, covering about 50 square miles of land, have been commercially productive at one time or another during the past half century. Approximately half that area remains in actively producing oil fields. Some fields are possessed of tremendous thicknesses of rich oil-bearing strata while others have thin strata which are quickly exhausted. Some of the fields occur in crowded urban

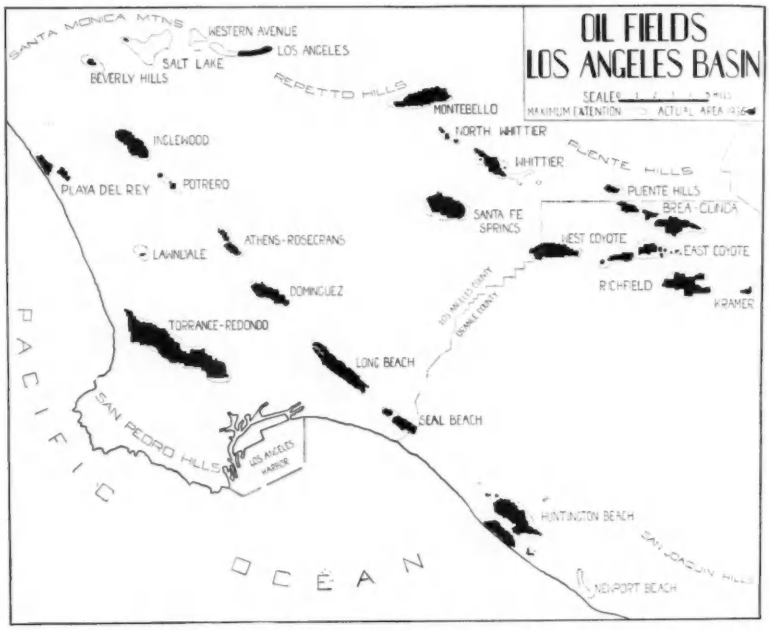


FIG. 1—Distribution of oil fields within the Los Angeles Basin. Areas producing in March, 1936 are shown in black. Dotted lines show the maximum extensions of fields.

territory, others in irrigated agricultural lowlands, and still others in brush-covered hill lands. Some fields are characterized by scores of diminutive leases resulting in very intense competition and uneconomical development, while others contain a small number of conservatively-developed leases of large size. Some fields, although a half century old, are still producing oil while others are practically abandoned although they were discovered less than a decade ago. Table I lists the fields in the order of their commercial development and summarizes the principal facts concerning their development and productivity.

The Los Angeles Basin, as viewed in a restricted geological sense, includes an area of about 900 square miles (Fig. 1). As is generally known, it is a northwest-southeast-trending structural basin or geosyncline with a length of approximately 45 miles and an average width of about 20 miles. The basin is bordered on the north and northeast sides by a series of complex faults and associated minor folds paralleling the base of the Santa Monica Mountains, Repetto Hills, and Puente Hills. Eight oil fields have

TABLE I

General Statistics for Oil Fields of Los Angeles Basin

Oil Fields	Year of First Commercial Exploitation	Producing Acreage March, 1936	Production before 1936. Million Bbls.	Production in 1936. Million Bbls.	Wells drilled before 1936	Average Number of Wells Producing in 1935
Puente Hills	1880	97½	With Brea-Olinda	With Brea-Olinda	101	With Brea-Olinda
Los Angeles	1892	280?	65	292	1,059	107
Brea-Olinda	1897	1,157½	154	3,612	562	362
Whittier	1898	485	17	379	315	162
Western Avenue	1899	0	With Los Angeles	0	98	0
Salt Lake	1902	17½	With Los Angeles	With Los Angeles	516	8
Beverly Hills	1908	62½	With Los Angeles	With Los Angeles	45	13
West Coyote	1909	930	76	3,554	398	45
East Coyote	1911	595	68	987	With West Coyote	78
Montebello	1917	1,067½	98	2,287	276	173
Kramer	1918	70	With Richfield	With Richfield	With Richfield	With Richfield
Richfield	1919	1,097½	78	2,804	484	244
Huntington Beach	1920	2,290	233	15,133	1,195	491
Long Beach	1921	1,265	552	26,563	2,312	1,195
Santa Fe Springs	1921	1,060	402	16,159	1,140	547
Torrance Redondo	1922	3,772½	80	2,498	909	485
North Whittier	1923	52½	With Whittier	With Whittier	With Whittier	With Whittier
Dominguez	1923	685	78	7,916	202	85
Newport Beach	1924	0	⅛	0	56	0
Athens Rosecrans	1924	282½	30	993	294	72
Inglewood	1924	857½	97	4,477	317	210
Seal Beach	1926	372½	72	3,381	281	111
Potrero	1927	67½	2	135	56	12
Lawndale	1928	10½	1	64	69	6
Playa del Rey	1929	422½	33	5,696	322	185
Totals		16,998	2,136	96,930	11,007	4,591

been developed along that zone of disturbance at elevations of 150–1000 feet above sea level. The Pacific Ocean and faults along the base of the San Pedro Hills border the basin on the west and southwest but at several places oil-bearing strata extend to undetermined distances beneath the sea.

An undulatory range of hills, with crests rising to heights of 100–500 feet above sea level and stretching for 45 miles in a northwest-southeast direction between Beverly Hills and Newport Beach, forms the principal topographic interruption within the limits of the Los Angeles Basin. The uplifts occurred so recently that erosion has not yet destroyed the generally smooth slopes of many hills whose surface contours correspond generally with underlying structural contours, thus facilitating the discovery of oil-bearing structures. Nine oil fields are arranged *en échelon* along that prolific oil-producing Inglewood fault zone.

A similarly arranged but much less conspicuous series of interrelated topographic and geologic highs parallels at a distance of about three miles the northeast margin of the Los Angeles Basin. Five oil fields occur along that uplift. The remaining fields occur between the major parallel zones of disturbance and on structures deeply buried beneath the alluvium which generally mantles the surface of the basin.

The oil fields of the Los Angeles Basin are generally remarkable for great concentrations of petroleum in small areas. Great thicknesses of oil-bearing strata are common, as much as 4,500 feet having been cored in the Long Beach Field. Ten fields have already averaged 100,000 or more barrels for each proved acre. The Long Beach Field, since its discovery in 1921, has produced more than one-half billion barrels of oil and the average recovery per acre has been more than 400,000 barrels.

The first areas to be drilled for oil were situated in the hill lands along the northeast margin of the Los Angeles Basin. Conspicuous seepages, associated with oil-sand outcrops in the strongly folded and faulted strata, called attention to the existence of petroleum. Early inhabitants collected the petroleum residue or "brea" accumulating on the surface about oil springs in Los Angeles City and in Brea Canyon (Brea-Olinda Field) for use as roofing and paving materials as well as for fuel. The extensive La Brea Rancho asphalt pits (Salt Lake Field), world-famous for their yield of Pleistocene vertebrate remains, also produced much brea for use in the pueblo at Los Angeles and for shipment by boat to San Francisco.

The delay in finding the larger and more productive fields in the Los Angeles Basin was related to the early policy of drilling for oil only where direct surface evidences were abundant. Unsuitable drilling equipment also delayed successful exploitation of deeper sands even when areas were

strongly suspected of containing oil in commercial quantities. Rotary drills did not generally displace the less efficient cable equipment until about 1917.

The years 1920–1924 constitute the period of sensational oil development in the Los Angeles Basin. During that period seven important fields were discovered and five of them involved town lot areas. Enormous quantities of refinable oil resulted which fortunately could be marketed in the Eastern States through the newly-completed Panama Canal, in competition with Mid-Continent oil. For the first time California petroleum moved beyond Pacific territory and became an important factor in world markets. During those years, too, the Los Angeles area experienced a phenomenal growth in population, in manufacturing, and in industry and commerce, much of which may be attributed to the discovery of oil.

Although several small new fields have been discovered in the Los Angeles Basin since 1925, they have not notably increased the output. For about a decade oil operators have been concerned mainly with the development of known fields and it has been demonstrated clearly that in some districts production can be increased greatly by exploiting deeper zones. Deeper wells have given new lease on life to such outstanding fields as the Long Beach, Dominguez, Huntington Beach, Richfield, and Santa Fe Springs.

LANDSCAPE TYPES IN OIL-PRODUCING AREAS

The surficial aspects of most oil field areas in the Los Angeles Basin represent the composite expressions of widely divergent efforts at human occupation of the land. All of the areas occupied by oil fields were earlier devoted to other economic uses such as watershed purposes, grazing, agriculture, or urban development. The discovery and intensive development of several oil fields led to rapid and nearly complete alterations in types of land occupance and in landscape patterns (Figs. 2A and 2B). In most instances less complete changes in human use took place following the discovery of oil and a composite of old and new occupance features appeared in the landscape. In still other cases the development of oil resulted in changes of little consequence in both the use and appearance of areas.

A number of factors explain the varying degrees to which the invasion of the oil industry has altered the earlier types of surface utilization and contributed to the appearance of succeeding landscapes. Among them are principally the resistance of the earlier land uses to displacement (as measured by the value of improvements such as buildings and orchards), the size of land holdings and oil leases, the richness of the oil deposit, the desire of the owner to maintain surface uses secondary to oil development, zoning regula-

FIG. 2A—The Santa Fe Springs District in 1921 showing the first oil wells invading a well-developed agricultural and suburban community. Citrus and deciduous fruits, alfalfa, barley, beans, truck crops, and eucalyptus plantings occupied most of the area.

tions, and lease restrictions. In addition, areas beyond the actual limits of oil production usually have undergone changes in surface utilization as will be shown in succeeding pages. The principal factor in determining the size and shape of areas devoted to oil production obviously is the extent of the proved underground accumulations of petroleum.

Since the oil fields of the Los Angeles Basin have been developed in three chief types of areas (hill, urban, and rural) with outstanding differences in resultant landscape patterns it will be convenient to classify and describe them on that basis. Some oil fields, however, will need to be considered under more than one classification for they include two or more types of land areas. Certain qualities more or less descriptive of all oil fields in the basin will likewise be mentioned.

Hill Districts.—The development of oil fields in the generally non-peopled, brush-covered hill lands along the northeast margin of the Los Angeles Basin has resulted in no widespread displacement of former types of surface utilization. The hill lands usually are too rugged for agriculture and the brush cover (chaparral) is of little value for forage. Only comparatively small areas had to be cleared of brush for oil field operations in the Whittier, Puente Hills, and Brea-Olinda fields. Owing to the great importance of the hill lands as a watershed the prevention of brush fires con-

FIG. 2B—The Santa Fe Springs District in 1928 from approximately the same position on the west margin of the oil field. Observe the extent to which the former landscape has been altered. (Compare with the United States Geological Survey Topographic Map of the Whittier quadrangle, scale 1:24,000.)

stitutes the most important general land utilization problem arising from the development of oil fields in such areas. Care must also be exercised in order that oil refuse and salt water pumped from wells do not pollute water courses tributary to lowland irrigated districts.

Since land values are nominal, since no real competition with other types of land utilization exists, and since leases generally are large in extent, oil fields may be operated in such areas economically until they are practically exhausted. The oldest operating oil fields in southern California are in hill areas, yet none have ever been spectacular producers. Only along lease boundaries where double rows of offset wells frequently occur is the number of wells notably excessive.

The surface aspects of oil fields in hill areas afford several interesting and unusual features. Access is usually practicable only through narrow-bottomed canyons and along privately constructed roads. Well sites are distributed unevenly but widely over canyon bottoms, slopes, and ridge tops. Frequently they have been carved out of bed rock. Secondary roads must be provided to reach sites of wells before construction can begin; where slopes are steepest materials are moved by cable and sled. In some instances, all wells are situated along canyon bottoms, on ridge tops, and along

FIG. 3—View to the east over the West Coyote Hills Field which is generally representative of the hilly fields rising from the floor of the Los Angeles Basin. Note the tank farm in foreground, the large repair shops at the left, a compressor plant on the hill top, and the conservative spacing of wells.

certain intervening contour lines, in order to simplify road construction. Pipelines for handling oil, gas, and water commonly remain on the surface because of obvious difficulties involved in submerging them and because of the lack of competing surface activities which might make underground pipelines desirable. Storage tanks, machine shops, and accessory structures are usually distributed along canyon bottoms, as are the company houses occupied by oil field workers. In order to reduce operating costs, many of the shallow, small-producing wells are pumped in groups of a half dozen or more by means of cables originating in centrally-located power plants. Many of the wells operate intermittently, for the yields average only a few barrels each day.

The low wooden derricks or tripods, the pumping of wells in groups from central power plants, the small wooden storage tanks, and the generally obsolete equipment employed reflect the early development of all or parts of the Whittier, Puente Hills, and Brea-Olinda fields. Aside from the irregular chugging of the gas engines in the pumping plants, the quiet of those areas has been little changed by the invasion of the oil industry.

Several of the oil fields along the Inglewood fault zone and along the Santa Fe Springs-Richfield uplift also occur on slightly elevated hill lands, parts of which are so rugged as to preclude cultivation. The West Coyote Hills Field occurs on an elongated dome rising prominently above surrounding lowlands (Fig. 3). The surface is moderately dissected and is covered with low brush having little grazing value. This field, unlike those in the Puente Hills to the north, is accessible from all sides although road-building had to be carefully adjusted to topography. Unlike the older fields equipment and field practices are nearly identical with those employed in newer fields on level areas.

The Inglewood Field likewise is situated in hill land and has field equipment resembling that in the West Coyote Field. Grazing opportunities are superior, however, for grass and other edible plants cover most of the Baldwin Hills. In places irregularly shaped tracts are cultivated. The Montebello Field occurs in part on hill land with surface conditions closely resembling those in the Inglewood Field.

Still other fields, as the Beverly Hills, Los Angeles, Dominguez, and Kramer, occur in areas of low hills. They more nearly resemble fields on lowlands, however, for their surfaces are in the main adapted for cultivation or for residential use.

Urban Districts. Urban districts in which oil development has been undertaken afford the most spectacular surface expressions of petroleum production as well as the greatest amount of disruption to earlier or intended land uses. The Long Beach, Huntington Beach, and Santa Fe Springs fields provide the largest scale illustrations of intensive town-lot development

FIG. 4A—The early development (1923) of the Long Beach Field as viewed from the northwest. The productive Signal Hill District corresponds with the topographic eminence. The new residential area occupying the center of the photograph was soon to be over-run by oil development.

in the Los Angeles Basin (Figs. 4 A and 4 B). Smaller town-lot districts occur in the Playa del Rey, Torrance-Redondo, Potrero, Athens-Rosecrans, and Seal Beach fields. The Los Angeles Field is the oldest town-lot field in the basin, having been developed during the period 1892–1900. It affords some interesting contrasts with the newer ones, as well as many similarities.

In heavily-producing town-lot areas where ownership of mineral rights is parceled out among many owners of small tracts, practically all the surface, except that devoted to streets, may be appropriated for oil production. In the Santa Fe Springs Field, for example, about 100 independent and closely drilled leases were established in a town-lot area of some 350 acres with the result that almost no types of former urban occupation survived.

In town-lot areas a forest of wood and steel derricks (122 feet or more in height) and an understory of pump houses, storage tanks, supply sheds, compressor plants, and other structures form a maze of surface equipment. Steel derricks are characteristic of newer wells and fields but frequently they are used in older fields to replace wooden structures destroyed by wind storms or rendered unsafe for other reasons. The streets do not contain derricks and other oil field structures because those areas have been deeded permanently for public use and they afford the only routes along which one may penetrate the field. This does not mean, however, that the strata beneath streets are not tapped for oil because wells on adjacent lots are often directed beneath such areas by means of whip-stock drilling.

FIG. 4B—The Long Beach Field in 1930 showing the northwest extensions of the field in the foreground. A portion of the city of Long Beach is shown in the upper right corner of the photograph. The viewpoint is slightly different from that in Figure 4A, but the crescent-shaped drives in the right center serve to orient the two photographs. (Compare with the U. S. G. S. topographic maps of the Clearwater and Long Beach quadrangles, scale 1:24,000.)

Building lots (50×120 feet or less in size) often constitute drilling sites in urban areas. Some leases provide scarcely enough space on which to construct the standard derrick with its 24-foot base, pump house, storage tanks, and boiler plant (Fig. 5). Commonly five, ten, or more wells are drilled where single wells would have been capable of extracting the recoverable oil. In town-lot districts nearly every well may be regarded as an offset well, and consequently leases call for immediate drilling when wells appear on adjacent property. Excessive crowding naturally ensues along with a pattern of well spacing which is highly irregular and which lacks all semblance of orderly and conservative development.

The formation of "community leases" by the owners of adjacent lots is a device used to reduce excessive drilling in some town-lot areas. Such group leases are to be seen especially in newer portions of the Long Beach, Huntington Beach, and Santa Fe Springs fields. A State law passed in 1933 prohibits the drilling of wells in new fields within 100 feet of the lease boundaries, thus providing approximately one acre of land for each well. Although not applying to established fields that regulation will prevent in part excessive drilling in fields yet to be discovered. Within the extensive

FIG. 5—The Huntington Beach Field as viewed from the ocean front. Note the close spacing of wells in the large town-lot section in the foreground and the more conservative and regular spacing in the left middle distance. The residential district street pattern and the ornamental street trees are the principal evidences of the former occupance. The settled portion of the town lies principally to the right of the photograph.

city of Los Angeles an ordinance now enforces the acre-per-well ratio in all fields.

It should be pointed out also that nearly all town-lot fields contain some acreage leases on which well spacing is comparatively satisfactory. The close spacing of wells about the margins of such acreage with fewer wells located near the center reflects the effort of each lease holder to protect his own interests in a mobile resource.

Vacant lots, decadent or abandoned houses, and paralyzed urban development are other primary characteristics of city areas which have been invaded by oil wells. Witness the square miles of residential subdivisions in Huntington Beach, Long Beach, Athens, Seal Beach, Lomita, and Santa Fe Springs, with miles of paved streets, sidewalks, ornamental street plantings, sewers, water mains, and power lines, and which hold almost no opportunity for additional residential development until the oil industry has been completely removed.

It is needless to emphasize that the discovery of oil in subdivided areas leads to wild buying and selling of lands, leases, and royalties on all conceivable bases. High pressure selling of "oil lots" to small speculators in purported residential subdivisions has been one means of securing exorbitant prices for land supposed to contain oil. Most of the vacant lots in oil fields of the Los Angeles Basin were never actually occupied by urban structures but represent lands which were subdivided for speculative residential use before or after oil was discovered. Scattered residences were characteristic, however, in most parts of town-lot fields developed in the basin.

Well-established urban districts have sometimes continued as residential centers despite the invasion of oil wells. Most residences in the fairly compactly settled central and eastern portions of the Los Angeles Field were not forced out in the early 1890's by oil derricks, the majority of which were constructed on intervening vacant lots. The attractiveness of the area for residential purposes, however, was destroyed, and its normal urban development was thoroughly interrupted. In the sections of the field where oil wells still remain few improvements are made to private or public property and some of the poorest residential districts of the city are to be found there today. Since that field was opened more than forty years ago and since it has experienced no recent revivals of drilling, the oil field equipment and practices resemble those already described in the Puente Hills and Whittier fields.

Most houses in the Venice beach resort settlement (Playa del Rey Field) were allowed to remain when oil development began in 1929 because sufficient vacant lots remained to meet most of the needs of the drillers. Many of the houses, however, were abandoned for residential purposes because of the intense noise, the fire hazard, and the general congestion of traffic which arises in any active oil field. Some families continued to occupy their homes in sections where derricks were not too closely spaced, hopefully awaiting the time when the industrial "blight" should pass. A few residences were utilized as field offices for oil companies, supply firms, and real estate ("oil lot") operators (Figs. 6A and 6B). The intense crowding of derricks in the Playa del Rey Field, although entirely unjustified on the basis of available oil, came about through the inrush of speculative one-well organizations. Many of them held leases on single lots 40×100 feet in size. Several well-drilling units occupied only the rear half of lots, the owner of the land continuing to occupy the house on the front half.

Urban areas of higher quality and especially if fully occupied may successfully resist invasions of the oil industry through zoning ordinances. Investments in such urban properties fortunately are recognized to be greater than any probable gain from the underlying oil and consequently the area is never opened to drilling. An illustration occurs at the northwest end of the Torrance-Redondo Field where zoning prevents the extension of the field to the ocean margin across the town of Redondo Beach. As it happens the oil produced in that end of the field is of low grade and production is small, facts which assist materially in maintaining the zoning restrictions. There is no assurance, however, that at some time permission will not be granted for extending the oil field to the ocean margin. A few wells have already been drilled near the ocean to the north of the Redondo Beach limits (Fig. 1).

FIG. 6A—Prior to the discovery of oil the Playa del Rey sand spit, bordered on the west by the ocean and on the east by the Ballona Creek marsh, had been subdivided and supported an attractive beach colony. Lots were small, streets narrow, and the artificially-dredged "Grand Canal" with its "Venetian" bridges provided one of the unique features of the resort. Equipment yard and compressor plant along slough in right middle distance. Photograph taken July 1, 1930, after the first derricks had been erected.

In Huntington Beach a small area at the southeast margin of the field which is occupied by an intensively developed commercial and residential district has never been opened to drilling although most sparsely-occupied and newer residential sections of the town have been thrown open by popular demand.

Zoning ordinances have prohibited the drilling of new wells or the deepening of old ones in the decadent Los Angeles Field for about 25 years because of the increased injury which would be done to that thickly-populated residential district adjacent to the center of the city. Increasing land values, steadily declining yields, and poor quality of oil are factors which underlie the legal restrictions. Unsuccessful attempts have been made to open other residential districts of Los Angeles from time to time.

The city of Inglewood, while not forbidding new wells in the Potrero Field, requires payment of a $500 fee for each drilling permit, thus discouraging some operations and also providing some recompense for such losses as may accrue to the city. Private property owners in the Potrero Field, who

FIG. 6B—This photograph, taken on December 6, 1930, or about five months after Figure 6A, shows the remakable speed with which landscape alterations take place when oil is discovered. The field was producing at its maximum rate at this time. All derricks are steel structures which give a distinctive appearance to the field. (See U.S.G.S. topographic map of the Venice quadrangle, scale 1 : 24,000.)

did not secure a cash bonus or a producing well, have suffered large losses in the valuations of lots and improvements. Most of the houses in three city blocks were moved to other locations in order to make room for oil-drilling operations during 1929. Many lots were not drilled as the yields of early wells were found to show rapid declines. By 1934, most of the wells in the Potrero Field had been abandoned but there was little evidence of recovery of the urban function.

The imposition of rigid requirements for oil well drilling and operation in some city areas reflects the growing sentiment against the unrestricted entrance of industrial activities into established urban areas. In the Playa del Rey Field, which lies chiefly within the western political limits of Los Angeles, petitions had to be granted permitting exceptions to the zoning ordinance before each well could be started. Bonds in the amount of $5,000 had to be posted to cover possible damage to property which might result from oil operations. Derricks were to be of steel for fire protection, and other safety measures were required on all well sites. Drilling had to begin within 75 days after the permit was granted. If drilling was discontinued

or if the value of the product from a well fell below $25.00 daily the permit was subject to cancellation. Upon abandonment of the well the surface of the lease had to be restored to its former condition so far as practicable within 60 days.

Cemeteries constitute a special type of land use associated with cities which has successfully resisted the invasion of the oil industry. In the midst of the Long Beach Field a cemetery containing about 20 acres has withstood the inroads of oil although productive wells crowd its borders on all sides. The sides of derricks bordering the burial grounds are lined with corrugated sheet iron to prevent oil well refuse from being blown into the cemetery. Proposals have been made to extract the oil from beneath the cemetery by drilling slanting holes from the exterior margins of the plot, but such procedures have been declared illegal. A large cemetery at Inglewood located at the edge of the Potrero Field likewise prevented a slight expansion of that town-lot field to the east.

Many anomalous features of urban land occupance occur in the oil fields reflecting various aspects of the competition between the incoming oil industry and established surface uses. In the southern portion of the Potrero Field several oil wells have been drilled in an attractive golf course. Oil royalties contribute to the income of that country club, however, and members willingly overlook objections arising from such incongruous uses of the land. At the north end of the Long Beach Field a country club received a cash bonus of $225,000 to open to drilling their lands, which soon were discovered to lie beyond the producing zone. The club profited greatly by the deal and yet escaped having their grounds appropriated by industry as they anticipated would happen. Near the center of the Santa Fe Springs Field a well-built community church is one remaining structure not associated closely with oil development. Church services continue to be held amidst the towering derricks and despite the deafening roar of oil pumps and compressor plants. In the Playa del Rey Field, on a lease 80×90 feet, an oil derrick rises through the roof of a commercial garage because a mortgage holder was unwilling to have the building torn away for fear the property would not be worth the amount of the mortgage in case oil was not discovered, and the oil company would not pay a sufficient cash bonus to cover the mortgage. In the Long Beach Field a triangular park space ($47 \times 30 \times 45$ feet) at a street intersection is one of the smallest oil leases in southern California containing a producing well. Through an error, the land was not deeded by the subdividers to the public for park purposes and it was sold to an individual before oil was discovered for the non-payment of taxes.

In addition to "destroying" residential areas the operation of oil fields

has also been responsible for the expansion of many urban centers and for the creation of a few small company settlements within the limits of oil fields. The highly urbanized character of the Los Angeles Basin and the fact that no oil field is many miles from established residential centers explains why no new "oil towns" such as arose in the southern San Joaquin Valley have appeared. Portions of at least half the fields of the Los Angeles Basin actually occur within the political boundaries of cities and towns. Many oil field workers also do not object to commuting five or ten miles. Thus the stimulative influence of oil field development on residential growth was felt very widely.

The extent to which Long Beach and other nearby centers profited from the development of the Long Beach Field may be suggested by the fact that, in 1923, about 10,000 men were employed in the field and the daily payroll amounted to $75,000. After drilling has been completed it should be remembered, however, that a comparatively small number of workers can carry on operations in any field.

The town of Brea, which lies within easy reach of five important oil fields at the eastern agricultural end of the Los Angeles Basin, probably owes most of its growth to the oil industry. The scant growth of Los Nietos at the very north margin of the Santa Fe Field is somewhat puzzling. Probably the relative closeness of that field to Whittier and the southern suburbs of Los Angeles explain it.

Several small company settlements of oil workers are to be found on the more isolated leases of major producers in the Whittier, Brea-Olinda, and Torrance-Redondo fields; but much larger camps of a similar type occur at Pacifico (near Taft) and Vernette (near Fellows) in the San Joaquin Valley. A few company houses remain in the old Beverly Hills and Salt Lake fields reflecting the former comparatively isolated character of those fields now completely surrounded by metropolitan expansion.

Rural Districts. In rural areas, where leases to large tracts of land may be secured by oil companies and where a conservative field development program is undertaken, individual wells are usually expected to recover the oil from 5–10 acres. Large leases with not more than five or six companies operating in the field are typical of the Dominguez, East Coyote, West Coyote, Montebello and Inglewood fields. The Dominguez Field is outstanding because it has been developed essentially as a unit by agreement among the several large operators. Most wells are spaced at intervals of approximately 600 feet, each draining about 8 acres. Offset wells along lease boundaries were eliminated by mutual understanding and drilling was limited to the upper oil zones until field conditions warranted deeper exploitation. Those policies explain the large and steady production of individual

wells and also the economical production which maintains throughout the field.

The characteristic uniform spacing of wells in conservatively developed fields at intervals such as 660, 528, or 440 feet, however, reflects slavish adherence to convenient fractions of the mile or the section of land rather than to scientific spacing of wells based on structural position, the characteristics of the reservoir rock, the physical nature of the oil, and the gas and water pressures. Economical spacing of wells also should take into account such factors as the depth of productive sands, the amount of oil available per unit of area, the probable future market price of oil, and the percentage of income which may be expected from invested capital.

On large leases the widely-spaced wells and their appurtenances may each normally require tracts of land only about 75×175 feet. Roads must be maintained throughout the tract in order to reach each well, and some land usually will be devoted to field offices, equipment yards, warehouses, compressor plants, waste water sumps, and a few small residences for workmen. Much land remains, however, the surface of which is not needed for oil production. That land usually is devoted to agriculture of the sort in

FIG. 7—Looking northwest across the Torrance-Redondo Field in March 1932 showing the manner in which agricultural operations are continued in much of that oil-producing district. The city of Torrance is situated near the center of the photograph while Redondo Beach and Hermosa Beach border the shore. (Compare with the U.S.G.S. topographic map of the Torrance quadrangle, scale 1: 24,000.)

vogue prior to the development of oil, providing that use does not interfere seriously with the oil industry (Fig. 7). Such agricultural uses include a wide range of types but consist chiefly of grazing on rough hill areas and barley production, bean growing, citrus fruit production, and truck gardening on tillable areas.

The predominance of annual or short-term crops, production of which may be discontinued without large loss on short notice, is in adjustment to the usual lease requirement that any portion of the land surface may be appropriated for oil production purposes at any time.

In the case of citrus and walnut groves the exceptionally high value of land and improvements and the long-term character of the crop have forced the oil interests to reduce to a minimum the amount of land appropriated for oil purposes (Fig. 8). Only as many trees are removed as is necessary to

FIG. 8—Looking southeast over the Richfield oil district toward the Santa Ana Mountains. In no other oil field within the Los Angeles Basin has the petroleum industry invaded such extensive tracts of citrus lands with so little damage to the agricultural development.

accommodate a somewhat more compacted well unit than is likely to be used where land is less valuable for agricultural purposes. Secondary roadways to reach wells are commonly fitted in between rows of trees and wherever practicable wells are located on waste land in order to avoid the removal of valuable trees. In the Santa Fe Springs, Richfield, North Whittier, and

Montebello fields the oil industry has invaded productive citrus and walnut producing lands. An attractive landscape is partially preserved, for the large, closely spaced trees hide many of the surface evidences of oil production in spite of the fact that the gaunt derricks rise a hundred feet above the tree tops.

The recent extensive planting of young citrus groves among oil wells in a portion of the Brea-Olinda Field lying on the frost-free valley slopes at the foot of the Puente Hills is an exceptional instance of the invasion of an active oil field by a long-term horticultural industry. The land department of a major oil company recognized an opportunity to make an appropriate secondary surface use of their property.

Any form of agriculture, such as dairying, which requires large tracts of fenced lands is likely to be forced out of an area when oil development begins. Two small dairies occur within the limits of the Torrance-Redondo Field but they include tracts of only about ten acres. Fences are fairly uncommon features in oil fields since they interfere with the movement of men and equipment especially during the development period, but also throughout the productive life of the field.

The extensive production of strawberries, bush fruits, vegetables, and flowers by Japanese farmers in several oil fields reflects both the advantages of short term crops in such areas and the difficulty often experienced by that race in securing leases on farm land in southern California. Rows of unpainted, portable, wooden houses occupied by the Oriental gardeners are especially numerous in the Torrance-Redondo and Dominguez oil fields. Smaller numbers of Japanese gardeners are found in portions of the Athens-Rosecrans, Long Beach, Lawndale, and Montebello fields. Most of the truck gardens are situated on large leases held by major oil companies whose wells are widely spaced. Certain large land owners have done more to encourage the development of truck farming by Japanese on their lands than have others.

Large tracts of sandy soils especially suitable for vegetables and berries also encouraged an intensive form of agriculture in a number of areas either before or after the discovery of oil. Land utilization maps constructed by workers of the University of California, Division of Soils, in 1916, show extensive tracts of gardens in areas now occupied by the Torrance-Redondo, Long Beach, and Montebello oil fields. Airplane photos show that truck gardening had invaded Dominguez Hill by the time oil was discovered in 1924. Aside from reducing somewhat the area available for agriculture, the principal effect of the entrance of the oil industry upon the Japanese gardeners on Dominguez Hill was the removal of all their homes for reasons of safety to points just outside the oil-producing district. Much gardening

continued as before on available areas among the oil derricks. Intensive development of the Long Beach Field, however, forced all Japanese farmers from their earlier stronghold on the top of Signal Hill to areas on the easterly slope outside the oil zone.

The availability of irrigation water is another factor which strongly affects the selection of crops and types of farming in certain oil field areas. Considerable tracts of unirrigated truck soils in oil fields near Los Angeles are planted to tomatoes, beans, and sweet corn only following ample winter rains. Those tracts lie fallow during the dry summer season and throughout years when markets are unsatisfactory.

Much land in oil fields is clean-cultivated in summer months to reduce fire hazards and is sown to barley during the winter. The barley is harvested for hay before it matures, and, therefore, it does not interfere with a careful program of fire prevention. Lima beans are grown as a summer dry-farm crop in a few small tracts of suitable land within the Baldwin Hills (Inglewood Field), that crop being grown extensively on the bordering fog-swept lowlands.

Bands of sheep are grazed on native forage during winter and spring months in the hilly Brea-Olinda, and West Coyote oil fields. Grazing assists in keeping down the growth of grass, weeds, and brush which otherwise would constitute a fire hazard. No feed is available during the dry summer and autumn months; then the sheep are moved to moist lowlands near the coast. Most of the Coyote Hills are owned by large ranch companies which engage in crop production on lowlands and in stock raising on unirrigated uplands. Sheep and horses are also grazed within the confines of the Montebello and Inglewood oil fields where slopes are too steep for agriculture and where most of the hill lands are included in large stock ranches established when land was cheap in southern California.

Much abandoned farm land occurs in oil districts about Los Angeles. The opportunity to use portions of the surface not required for oil production usually rests in the hands of the owner of the land if not otherwise arranged. Many owners, especially of small tracts of oil-producing land, make no attempt to utilize the surface for agricultural purposes, being content with incomes derived from oil royalties. The difficulty of fitting large-scale general farm operations into areas badly interrupted by roads, derricks, and other structures, often discourages any attempt to farm oil field areas suitable only for extensive crops. To supply irrigation water for intensive farming on small tracts is oftentimes uneconomical. Oil companies owning lands in fee may not wish to divert their attention to side-lines or to expose themselves to possible claims presented by tenant farmers for damages to crops or other possessions. Oil companies likewise find that fewer tools

and accessories disappear from derricks and supply yards when leases are not devoted to subsidiary uses. In portions of the Torrance-Redondo Field the principal field evidences of former agricultural use are the long evenly-spaced rows of tall eucalyptus trees which served as effective windbreaks in those areas of sandy soils.

Farm houses sometimes are abandoned when the owners move to town to live off their oil royalties. Orchards and vineyards, although not abandoned outright, receive less careful attention than formerly because they no longer constitute the principal sources of income for the owners. Ranch employees working under less direct supervision permit improvements and plantings to deteriorate. The uncertainty as to what the future holds for most oil field areas breeds a laxity in agricultural operations, a condition clearly recognizable in the field.

General Qualities of the Fields. The displacement or disruption of established land uses usually is not limited to the confines of oil fields themselves. During the developmental period especially, normal land uses may be disturbed for considerable distances in all directions beyond the proved limits of a field. The sale of oil leases and the possibility that wildcat wells may extend the limits of a field in any direction cause owners of land at least temporarily to divert their attention from agriculture and homemaking to efforts in the direction of securing oil leases and development on their own lands. Some cease farming operations to work for high wages in the oil fields. Even after the limits of a field have been rather definitely outlined oil companies may retain leases on property about the margins of the producing area in the hope that production may later be extended. Consequently zones of uncertainty in land utilization, desultory in appearance and wavering back and forth with marginal well completions and abandonments, commonly may be recognized about the borders of oil fields in both rural and urban districts.

Large tracts of land similarly are appropriated at the margins of many oil fields for tank farms, waste water disposal plants, gasoline extracting plants, field refineries, power substations, and oil well supply yards. Thus areas considerably larger than the tracts actually producing oil may undergo marked changes in economic use as a result of oil field development. The map showing land utilization in the Santa Fe Springs area illustrates all of those uses marginal to the field (Fig. 9).

The warehouses and yards of companies supplying oil field equipment, along with machine shops for repairing such materials, are characteristic features in most oil fields. Supply companies are most numerous in actively drilling fields and where the number of oil operators is greatest. An extensive industrial district along the northeast side of the Long Beach Field

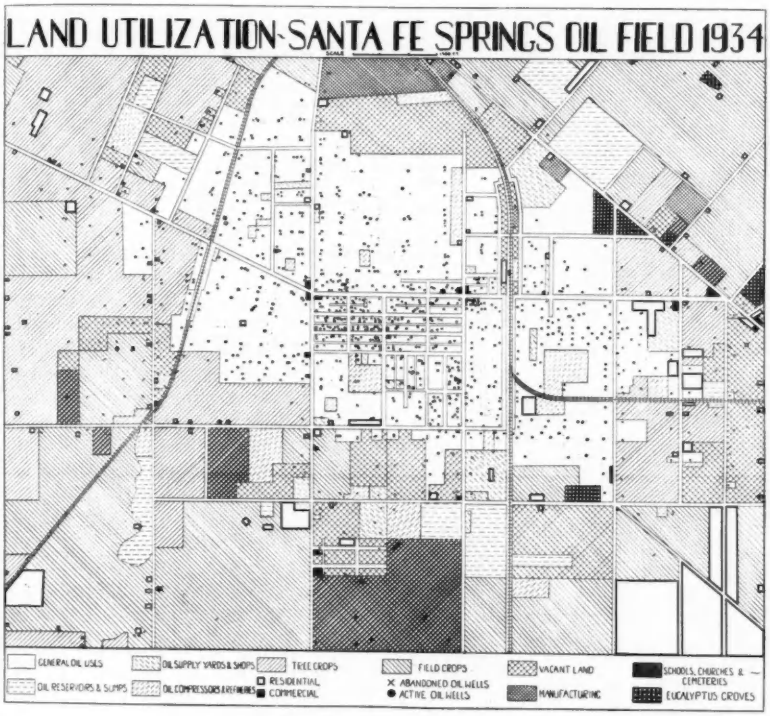


FIG. 9—Land Utilization, Santa Fe Springs Oil Fields, 1934. The map covers an area 2½ by 2¼ miles, or 5⅝ square miles. Percentages of land occupied by the major types of surface utilization are listed below. The figures for 1934 are drawn from planimetric measurements of this map; those for 1916 are from similar measurements of land utilization maps made by the University of California (Division of Soils).

Type of land utilization	Percentages	
	1916	*1934*
Oil production	0	28
General field crops	66	27
Tree crops	22	15
Eucalyptus	1	1
Vacant	1	10
Residences	no data	4
Schools, churches, and cemeteries	no data	3
Manufacturing	no data	2
Railroads	2	2
Highways	8	8

consists chiefly of machine shops and oil well supply warehouses and yards. In the least active and in decadent fields supply company warehouses and yards are usually discontinued. Major oil companies maintain their own supply and repair plants on their larger leases in each field.

Extensive tank farms occur at the margins of the Torrance-Redondo, Athens-Rosecrans, Long Beach, Dominguez, Huntington Beach, Santa Fe Springs, West Coyote, Brea-Olinda, and Montebello fields (Fig. 3). Most tank farms consist of numbers of large steel tanks with capacities of 55,000 barrels or more, evenly spaced, and bordered by earth dikes to retain the oil in case of collapse or leakage. Enormous cement-lined and covered excavations holding a half-million or a million barrels of oil are also a common type of storage basin used in tank farms. High border fences to keep out intruders, fire observation towers, and elaborate lightning arresting facilities are other characteristic features of tank farms.

Gasoline manufacturing plants occur about the margins or within the Dominguez, Montebello, Venice, Long Beach, Santa Fe Springs, Richfield, Coyote Hills, Huntington Beach, Seal Beach, Torrance-Redondo, Inglewood, Athens-Rosecrans, and Brea-Olinda fields. Such plants usually are constructed in medium and small sizes and duplicated as an oil field expands in order better to meet expanding or declining needs as well as to reduce fire hazards. The larger fields, however, contain compressor plants of exceptional size operated by large producers. Natural gas collecting and pumping stations operated by companies supplying gas for industrial and domestic uses in southern California are found in all of the larger fields. The largest refineries and tank farms in the Los Angeles Basin are situated within easy access of the harbor. The chance distribution of all the Los Angeles Basin oil fields within a 25-mile radius of the harbor district greatly facilitates the delivery of the crude product to the major storages and refineries.

Modern waste water and mud reclamation plants serve the Long Beach, Brea-Olinda, Coyote Hills, Richfield, Santa Fe Springs, Whittier, and Montebello fields and make unnecessary the maintenance of sump holes at each well as was the former universal practice. Oil-covered sump holes constitute a serious fire hazard in oil fields and overflows during rains often cause much damage to agricultural and residential areas. Modern plants collect the waste water, mud, and refuse oil by pipeline from entire fields. They extract the solids and the oil, and deliver the salt water through pipelines as much as 16 miles in length to the ocean. The great quantities of salt water produced in oil fields unquestionably would lead to the serious contamination of irrigation and domestic water supplies if they were allowed to enter natural drainage channels and underground reservoirs.

The more important oil fields of the Los Angeles Basin are intensive centers of industrial activity. They compete with great steel plants in creating noise. They surpass all ordinary mining properties in their display of mechanical equipment on the surface. The hundreds of producing units, nearly identical in appearance, in an oil field are in marked contrast to the great variety of structures and types of plants found in the usual manufacturing or mining district. Batteries of large compressor engines, tall absorption units, massive cooling towers, and great steam plants provide a distinctive manufactural aspect to portions of most oil fields. Oil fields stand out impressively in the landscape of the Los Angeles Basin. Those situated on hill lands, like the Inglewood, Montebello, Dominguez, Signal Hill, East Coyote, and West Coyote fields, provide imposing sky line features visible for many miles.

The comparatively short life in prospect for most oil fields, the fire hazards, and the ease of transporting oil and gas, as well as oil field supplies, militate against the establishment of permanent manufacturing industries within or near individual oil fields. The majority of such plants are situated in the large diversified industrial districts associated with Los Angeles, because of better access to labor and because such sites are within easy trucking distances of all oil fields within the basin. Centralized locations also afford better opportunities to serve markets outside the local basin.

The ease of transporting petroleum by pipe-line makes it possible for oil fields to function even though they are not served by bulk-carrying transportation agencies such as railroads. Pipe lines and automobile trucks provide the only means of transportation in half the oil fields of the Los Angeles Basin. Nearly all the oil fields are crossed by one or more modern public highways. Although several oil fields occur near tidewater no provision is made for direct ocean transportation. Except for two or three instances it appears that all oil fields having direct railroad connections do so by accident, since the railroads were constructed long before any oil was produced. Furthermore, most of the oil fields make very little use of the immediate railroad facilities, especially after the major drilling operations are completed. A little-used railroad crossing a portion of the Long Beach Field is closely bordered by a line of oil derricks drilled by the railroad company in order that it might share in the wealth obtained from oil if not from the *transportation* of oil-field products. In December, 1935, the Railroad Commission approved an application for the line's abandonment. At Huntington Beach a line of wells along the waterfront is also situated on a railroad right-of-way (Fig. 5).

The volume of materials moving out of a productive oil field is enormous. Several of the larger fields in the Los Angeles Basin have produced from

100,000 to 300,000 barrels of oil daily throughout the periods of flush production. There is little surface evidence of that movement however, because of the intricate network of underground pipelines used to collect both oil and gas from each well for delivery to tank farms, refineries, and consumers. In the smaller fields, where the volume of petroleum handled is insufficient to warrant the construction of trunk pipelines, automobile trucks and trailers haul the crude product to refineries. Such is the practice also of many small producers situated in the larger oil fields.

Most oil fields, instead of being dependent on outside sources of fuel and power, utilize a portion of the natural gas which they have produced for power development. Some leases, however, are operated by hydro-electric energy developed in the southern Sierra Nevada Mountains, more than 250 miles distant. The newer fields contain most of the wells operated by electricity, but its use seems to depend largely on the abundance of gas in a given field, and on the ability of the operating company to use that form of power economically. On some leases electric power lines extending between rows of derricks are as conspicuous as they are along the streets of urban communities. Electric motors greatly reduce the operating noises in oil fields and simplify the individual pumping units, both factors of real significance especially in town-lot areas.

RETURN OF SOMEWHAT PERMANENT LAND USES TO ABANDONED OIL FIELDS

Although the displacement of former land uses by the mushroom-like growth of an oil field is far more spectacular, the usually slower return of somewhat permanent land uses to a declining or abandoned oil district is equally interesting. Within the Los Angeles Basin two fields have been entirely abandoned—the Western Avenue and Newport Beach fields (Fig. 1). Six others are largely abandoned, including the Los Angeles, Salt Lake, Beverly Hills, Potrero, Lawndale, and North Whittier. All remaining fields show areas of abandonment of varying sizes about their borders. Thus sufficient field evidence is available even at the present time to arrive at some tentative generalizations regarding the establishment of succeeding types of land utilization in southern California oil fields. Much additional evidence will be available in another decade. It should be pointed out, however, that abandonment of land by the oil industry does not necessarily mean that all the oil has been extracted from those areas. Many wells prove to be economically unprofitable at the present status of the industry and as a consequence they are driven out by competitive land uses.

It appears that the usual sequence in the Los Angeles Basin is for the land to return to its earlier use. Such return is in part due to the fact that

the former use may never have been fully obliterated by the temporary industrial invasion. The interval of time during which oil production occupies a given area is relatively so brief that the general stage of economic development of the area usually has not advanced notably beyond the original stage.

The return or expansion of urban uses is comparatively slow after most oil fields decline. Usually a few wells continue to produce for some years after the majority of wells are abandoned. Such operating remnants are very effective in keeping the district unattractive for residential purposes. The general and unfortunate oversupply of subdivided real estate in Los Angeles and vicinity also militates against the reoccupation of many residential districts which have gone through the oil cycle. A less attractive type of residential development than might otherwise have arisen seems to develop in most urban areas following the gradual removal of the oil industry.

The return of agricultural activities to declining oil field areas offers fewer difficulties for the economic displacement has been less complete and the elements of beauty and quiet in surroundings are of minor consequence. As rapidly as lands are cleared of oil field equipment, crops and pasture usually remove the scars of industrial exploitation. In hill areas the brush cover soon closes in the temporary gaps.

The abandonment of an oil field and its return to more permanent uses involves extensive field operations which in many respects resemble the activities accompanying the development of a new field. "Restoration of the surface to its former condition" requires considerable time and effort on the part of the lease holders, but it lacks the tense speculative atmosphere. Oil wells themselves must be partially filled with concrete in accordance with State laws in order to prevent the infiltration of water into oil horizons. Oil sumps must be burned out or cleaned out and the salt-impregnated mud buried deeply or hauled away. Oil-soaked soil also must be removed from beneath well platforms and about storage tanks and loading racks if there are to be any plantings at a later date. Large amounts of materials used in the surface structures, such as derricks, pumping plants, and storage tanks, as well as miles of underground oil, gas, and water pipes, must be removed. Such materials along with the casing which can be extracted are promptly reclaimed for use in future operations. Lease, fire, and public safety regulations are motivating factors which normally bring about a prompt clearance once an operation has been abandoned. In town-lot fields the ubiquitous realtor renews his activities and recent "oil lots" become "view lots" or commercial frontage.

The Salt Lake Field is the largest field in the Los Angeles Basin, both in areal extent and in production, which has thus far been essentially aban-

FIG. 10A—A view to the northwest across the Salt Lake Oil Field District in 1922. Rossmore Avenue marked the western limit of city expansion but Wilshire Boulevard, Third Street, and Melrose Avenue extended for several miles farther westward through or along the margins of the oil field. La Brea and Fairfax Avenues are seen to bisect the east-west roads at mile intervals. The expansion of Hollywood toward the west along the foot of the Santa Monica Mountains is clearly shown. (Compare with the U. S. G. S. topographic map of the Hollywood quadrangle, surveyed in 1923, scale 1 : 24,000.)

doned. Its sequence of land occupance differs from that observable in most fields in several interesting ways. The type of land utilization succeeding oil development differed from that preceding oil because during the oil period the general locality had progressed to a higher stage of economic utilization. Furthermore, the succeeding form drove out producing oil wells in wholesale manner and with surprising rapidity. The field was an important oil producer for two decades and its entire life span covers scarcely more than three decades.

The field was opened in 1902 on the gently sloping lands of Rancho La Brea, seven miles west of the center of Los Angeles. The area was then devoted to grain growing and to grazing. The land was held in large units and the ranch houses were widely spaced. Wilshire Boulevard, then a dusty country road, skirted the oil field on the south and the outlying villages of Sherman, Hollywood, and Colegrove lay some distance to the north of the oil field. An electric railway bordered the field on the west and it was utilized along with wagons and a pipeline in sending oil to local markets. Storage capacity in the field provided for about a half million barrels. Agri-

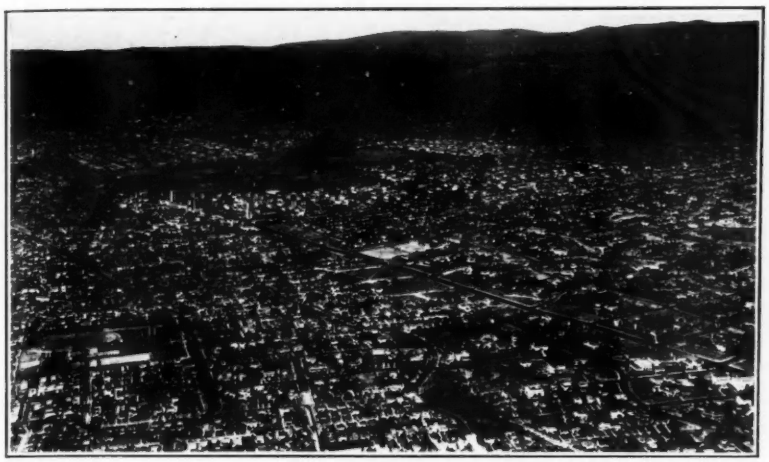


FIG. 10B—The same area in 1930 showing the extent to which the oil field was replaced by residential and commercial development. The cloud of smoke rises from a sump hole which was being burned out in the process of clearing away the oil field. By 1934, all the wells in the area near the sump fire had been removed, the eight remaining in the field being situated one mile farther west.

culture and grazing were conducted between oil field structures approximately as before oil was discovered.

Most of the wells drilled in the field were completed by 1912 and no new drilling took place after 1920. About a dozen operators were located in the two square miles of productive territory but comparatively little over-drilling took place except along lease boundaries. The peak production took place in 1908 or 1909 when about four million barrels of oil were produced yearly thus giving the field first importance in southern California. The quality of oil from the Salt Lake Field was comparatively low.

With the growth of Los Angeles, populations spread westward along the foot of the Santa Monica Mountains, and Colegrove, Hollywood, and Sherman were enveloped in one continuous urban foothill belt (Figs. 10 A and 10 B). The city was also crowding the oil field on its eastern boundary by 1922. Due to the fact that wells in the shallower east end of the field were less productive than the deeper wells to the west and because of the exceptional opportunity for selling subdivided land at high prices, all wells lying to the east of La Brea Avenue and also a number lying immediately to the west of that line were abandoned by the several operators in 1924. The area was promptly cleared of all oil field equipment and was devoted to residential uses. La Brea Avenue became a principal north-south commercial

street bordered by blocks solidly filled with apartment houses and single family residences. The easternmost portion of the oil field was occupied by handsome homes adjacent to the extensive Wilshire Country Club golf course which had been created just to the east of the oil field.

At the same time Fairfax Avenue was opened across the oil field as another major north-south commercial street one mile to the west of La Brea Avenue. All wells to the west of Fairfax Avenue between Wilshire Boulevard and Third Street were abandoned and the area devoted to apartment houses and small residences.

Beverly Boulevard was then extended westerly across the oil area and finally La Cienega Boulevard was opened one mile to the west of Fairfax Boulevard as the third north-south commercial street crossing the oil field. An especially productive well happened to lie along the survey for La Cienega Boulevard near Third Street and in order to save it the pumping plant was realigned and the roadway divided so that at present the well occupies an island in the center of the boulevard.

As other leases expired more wells were abandoned until, in 1930, only 27 wells remained in the Salt Lake Field. By 1934, the number was reduced to eight, all located on a small lease near the intersection of Third Street and La Cienega Boulevard. The Salt Lake Field served as a barrier to the normal westward expansion of the city until 1924, but at that time the availability of large tracts of suitable land facilitated a rapid and well-planned expansion of the city over most of the area. One is led to speculate, however, concerning possible disadvantages or even hazards which might result from locating a house directly over an oil or gas well regardless of how well it has been plugged.

In 1936, the principal remaining evidences of the formerly extensive oil field included the eight wells, one large steel storage tank, an oil-loading rack along the electric railway, and a small steam plant. The La Brea asphalt pits which had attracted attention to the area as a possible oil field were included in an attractive city park. A considerable tract of land at the southeast corner of Third Street and Fairfax Avenue, which was cleared of oil wells in 1930, remains vacant or is devoted to temporary commercial uses. A large wooden stadium, an exhibition pavilion, various other recreational concessions, flower stands, nursery sales yards, and other small retail establishments occupied most of the boulevard frontage of that tract. Had it not been for the slump in real estate activities after 1929, it is likely that the entire oil field area would have been devoted to substantial urban uses even more promptly.

The Los Angeles Field is another which has essentially completed the cycle of oil occupance. A number of the original 800 wells drilled in the

central and eastern portions of the field remain chiefly because the principal growth of the city has been in other directions. The crowding of wells, the restrictions placed upon drilling by city authorities as early as 1905, and the comparatively small original reserve of oil underground, contributed to the steady decline of the field. At the outset, the best wells produced only about 60 barrels daily, and as early as 1906 the average daily yield was only about 4 barrels a well for the field. In 1932 they produced about 1½ barrels each daily and in 1936 about ½ barrel each. All of the nearly 100 wells drilled in the Western Avenue Field were abandoned before 1912 as were most of the 350 wells drilled in the western third of the Los Angeles Field. Street extensions and widening programs have reduced the number of wells in the eastern end of the field in recent years. The Western Avenue Field and portions of the Los Angeles Field therefore produced for a decade only, after which they were displaced by substantial residential development.

The Beverly Hills Field occupies a small rise of ground which is almost surrounded by various forms of urban development. It now interferes with the completion of several important streets leading from the commercial core of Los Angeles westward to the large Santa Monica and West Los Angeles residential districts. The objections to such industrial development by residents of fashionable Beverly Hills will undoubtedly lead to the abandonment of the field upon the expiration of leases.

Other fields have suffered even more serious declines in production and in numbers of producing wells in much shorter periods of time. The small Newport Field expired after less than a decade of operation. The small North Whittier Field is certain to be crowded out in the near future because of competition with other land uses and because the oil zone shows rapid ingress of water. The wells are scattered among rich avocado and citrus groves and are adjacent to fine homes overlooking the town of Whittier and the lower San Gabriel Valley.

An important consideration in a discussion of land utilization in oil field areas is the probable life remaining for the various fields. Knowledge of the time at which a given area would be available for other uses would facilitate planning for future land utilization. Since that in itself is a large problem and since it must take into account also such unpredictable factors as the extent to which the fields may voluntarily be "shut-in" and the likelihood that new zones of production may be discovered, no attempt will be made here to predict when any field will be abandoned.

THE NEED FOR UNIT DEVELOPMENT AND LAND CLASSIFICATION

In conclusion, it may pointed out that from the viewpoint of land utiliza-

tion, the development of several oil fields in the Los Angeles Basin has resulted in economic losses rather than gains. Excessive drilling in town-lot fields has resulted in large direct losses to many investors because the expenditures in well-drilling and operation exceeded the value of the oil which was recovered. Although some property owners have gained by acceptance of cash bonuses and royalties, the community as a whole frequently has lost through the disruptions to normal land uses. The need for developing oil fields as geologic units is clearly evident. Careful consideration should be given to the probable losses as well as to the gains before any established land uses are permitted to be displaced by oil development activities.

The development of an oil field brings temporary ruin to a residential district, and since permanent industries are not introduced, the beneficial effect upon local industrial activity is temporary. Some cities now notably dependent upon oil fields for their growth and sustenance may well direct their efforts toward securing replacement industries to be established as oil production diminishes.

A few cities have profited from oil development in unexpected ways. In Long Beach large acreages of municipally-owned park and water-bearing lands were found to contain oil in large quantities. For a decade the royalties from those leases have enriched the municipality by about a million dollars annually. That income made possible the provision of recreational features and other permanent improvements which probably could not have been secured through taxation. The city of Signal Hill, said to be one of the wealthiest of small municipalities, is an interesting instance of creating a separate industrial city within the bounds of Long Beach in order that oil might be produced there with as little interference as possible.

The effects of oil development upon land utilization in rural areas have been less destructive economically largely because more efficient exploitation of the deposit is possible where land holdings are larger. The recovery of valuable mineral resources usually more than balances the losses from temporary interruption in the normal utilization of land surfaces for most types of agriculture. Where the surface continues to be used for crop production, while at the same time the underlying minerals are recovered, a satisfactory and profitable type of "two story" land utilization is realized.

University of California at Los Angeles.

March, 1936.

The Basin Settlements of the Middle Sierra Madre Oriental, Mexico*

SAMUEL N. DICKEN

From northern Coahuila to southeastern Puebla, an airline distance of 900 miles, the Sierra Madre Oriental presents a variety of physical and cultural qualities. In general the changes are progressive: from north to south the altitude, ruggedness and humidity increase; population density is also greater to the southward. The northern section of the sierra, as far south as Monterrey, is more like the dissected edge of an arid plateau than a mountain range; mesa and basin alike fallow for want of rain. The middle section, from Monterrey to the 23d parallel (Fig. 1) has humid ranges and arable basins, but the humidity of the ranges is scarcely sufficient to water all the basins. In the southern section the highest peaks reach into the zone of permanent snow; precipitation is greater, both on account of altitude and latitude, and most of the basin land is cultivated. Thus the Middle Sierra Madre is intermediate in quality as compared with the northern and southern sections.

The Middle Sierra Madre rises abruptly from a piedmont lowland at 1,000 feet to a series of long parallel ranges, varying in elevation from 6,000 to 12,000 feet. Between the ranges lie numerous basins at about 5,000 feet. Communication from basin to basin offers only minor difficulties, but this rugged range as a whole is a distinct barrier between the piedmont and the plateau. South of Monterrey for more than 150 miles no easy westward route appears. As a result the region is distinctly handicapped in shipping out its products, such as wheat and lumber, to the east.

The sierra proper shows a sharp contrast with the escarpment (Fig 1): the ranges are parallel to the general trend of the mountains, whereas the spurs and canyons of the escarpment are at right angles to the sierra and slope steeply to the piedmont. The contrast with the basin-range region on the west is largely in the altitude and humidity of the ranges. In the basin-range region the basins are dominant, the ranges low and arid; in the sierra the ranges are loftier, more closely spaced and are important factors in the utilization of the basins. In short the Middle Sierra Madre Oriental is a range-basin region.

* The field work on which this report is based was aided by a grant from the Fluid Research Funds of the University of Minnesota.

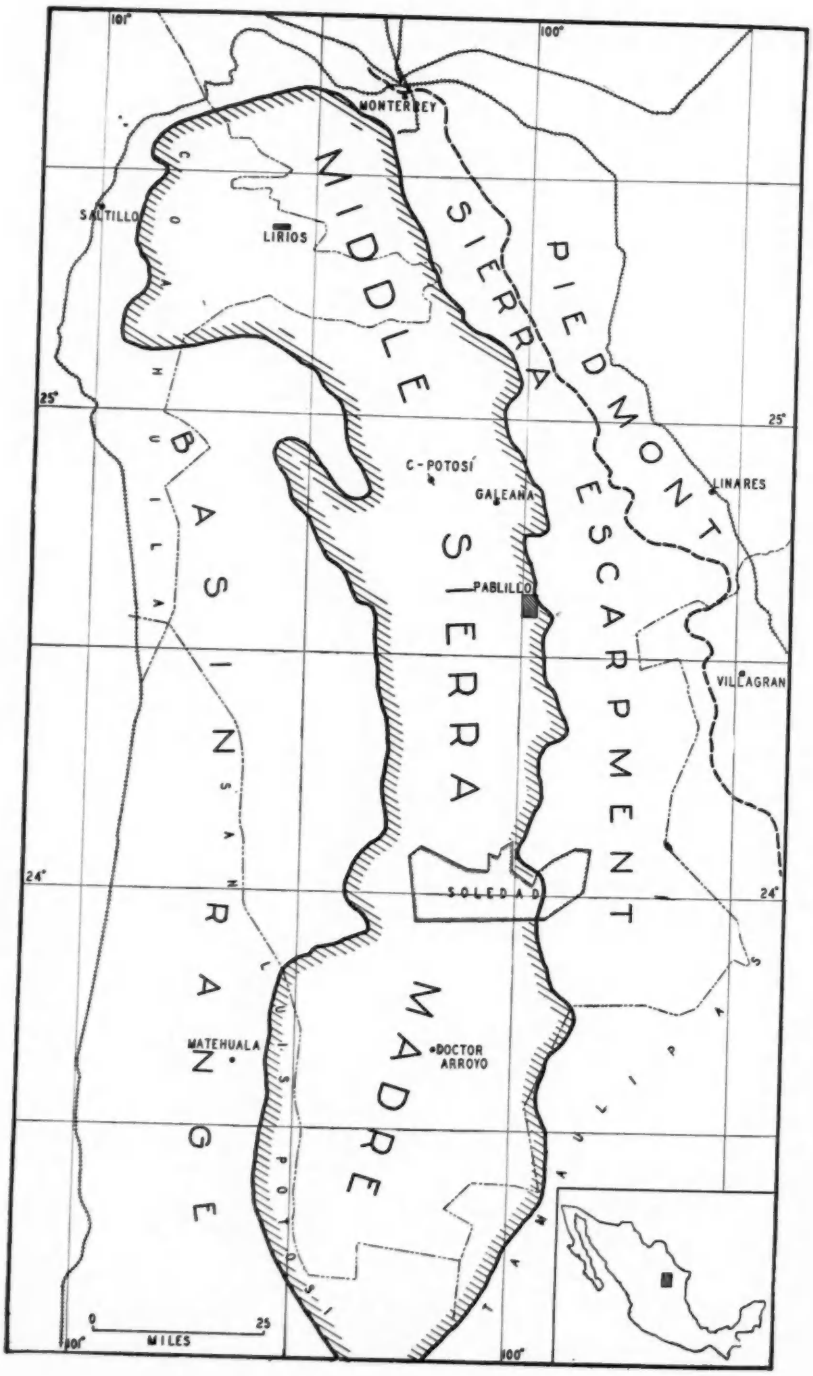

101°
100°
MONTERREY
SALTILLO
LIRIOS
MIDDLE
SIERRA
PIEDMONT
ESCARPMENT
25°
C-POTOSÍ
GALEANA
LINARES
BASIN RANGE
PABLILLO
VILLAGRAN
24°
SOLEDAD
MATEHUALA
DOCTOR ARROYO
SIERRA MADRE
0
25
MILES
100°

FIG. 1.—Sketch map of the Middle Sierra Madre Oriental and parts of adjacent regions. The heavy fringed line marks the approximate boundary of the region, within which Lirios, Cerro Potosí, Pablillo and Soledad are indicated as type areas. The heavy dashed line separates the sierran escarpment from the piedmont and the angular boundary of the state of Nuevo Leon is shown by a lighter dashed line. Railroads (solid lines) are added to indicate the isolation of the region. The outline of the Hacienda Soledad corresponds to Figure 4.

Of the four regions in the vicinity (Fig. 1), only the piedmont lowland and the sierran basins offer many favorable sites for settlement; the escarpment has little level land and the basin-range region is too arid. The settlements of the piedmont lie in the valleys at the foot of the escarpment and use water from the canyons of the escarpment for irrigation. In the sierra most of the settlements are located in the most favorable sites of the alluvial basins and utilize water from the adjacent humid ranges. It is with these basins and ranges of the middle Sierra Madre Oriental, their physical qualities and occupance, that the following discussion is concerned.

CLIMATE OF THE MIDDLE SIERRA MADRE

The climate of the middle Sierra Madre is generally characterized as semi-arid mesothermal (**DB'da** of Thornthwaite)[1] with maximum summer rain but deficient at all seasons. From the short record of one station in the region, and three more in the vicinity,[2] only one type of climate is indicated. There are, however, strong contrasts in temperature between the higher mountain ranges, even greater variation in rainfall between the mountain slopes and the sheltered basins. There is also great variation in rainfall locally, corresponding to exposure: east slopes are comparatively humid, rain shadow slopes arid. Basins with high ranges to the east are dry, but where the trend of the ranges exposes the basins to the east winds the rainfall is much greater. On the basis of the natural vegetation, elevation, exposure, and soil type, observed in the course of the field study, it appears that two types of climate have wide distribution in the region: the semi-arid mesothermal in the valleys and basins of the sierra and the subhumid mesothermal winter dry type (**CB'w** of Thornthwaite)[3] on the slopes and summits of the higher ranges. On the evidence of existing settlements it may be said that most of the basins are too arid for agriculture without irrigation, except for small grains in the more favored

[1] Thornthwaite, C. W., The Climates of North America. *Geog. Rev.* 21: 633–655. October, 1931.

[2] Galeana, elevation 5400 feet; Saltillo at 5240; Monterrey at 1765; Ciudad Victoria at 1050. All are semi-arid mesothermal stations. The first two are in mountain basins, the others in the piedmont.

[3] The atlas *México en Cifras*, Departamento de Estadistica, Mexico, D. F. 1934, p. 5, shows an area of **CB'w**, which, however, does not extend far enough west.

FIG. 2.—Ranges and Basins of the Middle Sierra Madre Oriental (ranges shaded). Modified from the Carta de la Republica Mexicana, 1:100,000. The varying ratio of mountain and basin land, the altitude and trend of the ranges are fundamental qualities of the natural landscape.

localities. Furthermore most of the higher ranges are humid enough to support a forest cover.

LAND FORMS AND GROUND WATER

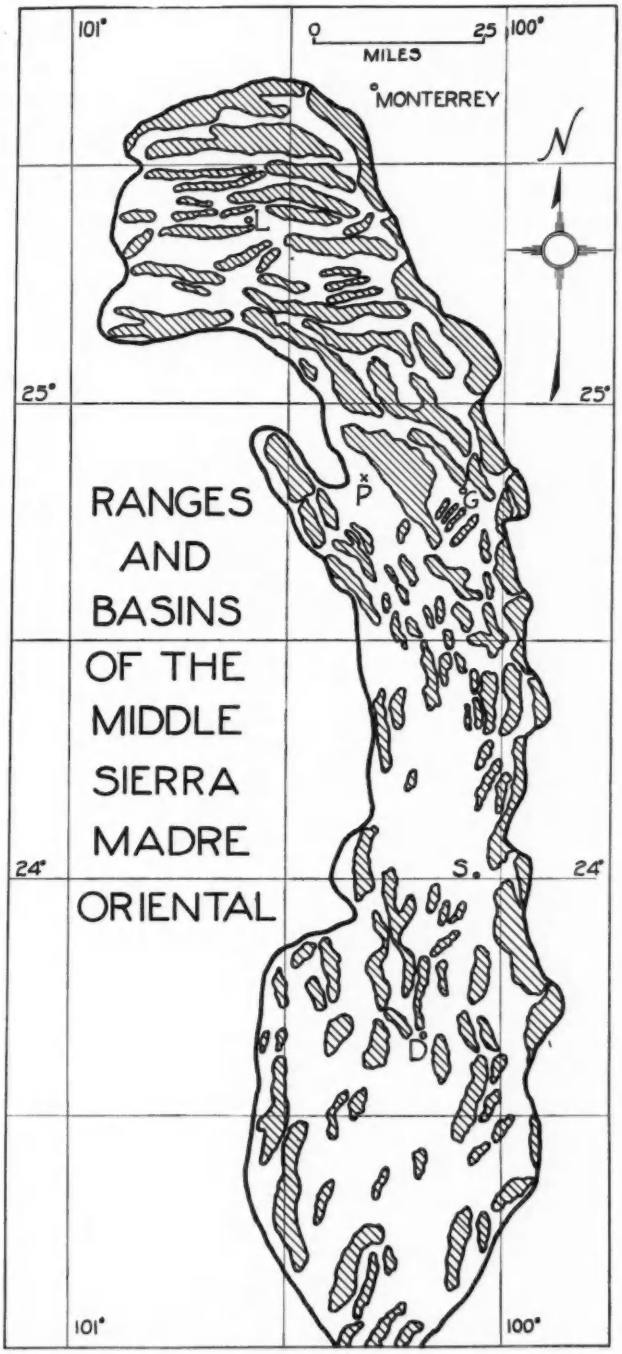
Many of the ranges of the middle Sierre Madre are in the form of cuestas or hogbacks developed on the folded and faulted limestones, which comprise most of the exposed bedrock.[4] The folds are overturned toward the east and the outcrops appear in isoclines dipping sharply to the west.[5] The strike of the ranges is usually slightly west of north (Fig. 2), except in the northern part of the region where it is almost west. Between the ranges are the basins, large or small, narrow or broad, many of them including closed depressions which are due partly to valley filling, partly to the solution of the underlying limestones. Few of the valleys contain perennial streams, but widespread movement of water in sub-surface channels is indicated. Springs are common throughout the region, most of them occurring on the lower slopes of the ranges, at the margin of the alluvial basins. Altogether a large portion of the settlements depends upon springs for irrigation and water supply. At the time of settlement, when wells could not be drilled, springs were even more important than today. The most important factor affecting the distribution of springs and ground water is the structure of the limestones and the nature of the sediments in the alluvial basins. Since many layers in the limestones are relatively impermeable there is a strong tendency for the ground water, or more properly speaking the karst water, to move down dip and overflow in springs at the foot of the dip slope. At the foot of the opposite escarpment slope, springs are rare. Throughout this region most of the important settlements are located at the foot of the dip slope, usually on the lee side, where the springs are largest and where basin land is available for cultivation.

HISTORY OF LAND OCCUPANCE

The details of occupance in the Middle Sierra Madre Oriental during the early part of the 17th century are largely lost. Early travelers rarely

[4] Böse, Emil, Vestiges of an ancient continent in northeast Mexico. *Am. Jour. Sci.*, 5th Ser. Vol. 6, pp. 127–136, 196–214. 1923.

[5] Baker, C. L. Tectonics of the eastern Mexico Cordillera and the Laramide thrusts of trans-Pecos Texas. (abstract) *Geol. Soc. Am. Bull.* vol. 41, No. 1, pp. 168–169, March 1930.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crossed the region; then, as now, the main routes of travel lay to the east and west. According to local traditions the settlers were mostly Spaniards and other Europeans, who brought with them from central Mexico numerous followers. Very little is known about the Indians living in the region at the time. Local histories[6] describe them as nomadic but the climate of the region, together with the numerous favorable sites, cast a reasonable doubt on this account. Whatever the condition of the Indians, is it probable that their effect on the present culture was less than in any other region in Mexico. Doubtless most of them were killed or driven out; those remaining were absorbed with little influence on the invading culture.

TYPES OF OCCUPANCE

The first settlements were on large grants of land obtained by individuals or, in a few cases, by groups. Many of the grants included hundreds of square miles of mountain and basin land, only a part of which was arable. Although the largest holdings have been divided and subdivided by inheritance and sale, the average size of properties is still large. Within the regions as outlined in Figure 1, with an area of about 4,000 square miles, there are only 610 properties, many of which are more than 100 square miles in extent.[7]

The population of the Middle Sierra Madre is distinctly nucleated in certain favored sites, separated by uninhabited mountain and basin land. Most of the settlements are located in the smaller basins, usually at the points where ground water is easily available, either from springs or shallow wells. There are very few wells deeper than 100 feet and, although it is probable that the limestone underneath the basins would yield much more water, the mineral content would be high. The settlements use only ground water available near the surface and as a consequence much level basin land is unused. Although more than 50% of the total area is level enough to cultivate, less than 2% of the land is in crop. Expressed in another way, there are about 40,000 people in the region, with an area of 4000 square miles.[8]

Settlements include towns, *haciendas, ranchos* and single family establishments. Distinction of these types is based largely on size and ownership of land. Towns include the large settlements in which the ownership

[6] Cosseo, David Alberto, *Historia de Nuevo León.* Monterrey, 1925. 6 vols.

[7] *México en Cifras, cit.,* pp. 32–27.

[8] Estimated from data supplied by the Departamento de Estadística Nacional, for the 1930 census.

of the land is divided among many families; usually a half dozen families own most of the land, which is worked by "share cropper" peons. The population may be 50 or 3,000. The *hacienda* and the *rancho* are owned by single families but they may have the general aspect of a town or village. For purposes of taxation or because of inheritance, the lands of an *hacienda* may be legally vested in many persons including minors, but in practice it operates as a unit. The *rancho* differs from the *hacienda* only in its smaller size but the distinction is not sharp. In practice *rancho* may also indicate a smaller settlement on a large *hacienda,* such as Amaro at Soledad, or it may be applied to a single family settlement.

PRODUCTION

Productive activity in the region, may be classified under five headings: (1) subsistence corn agriculture, with or without wheat; (2) commercial wheat agriculture; (3) grazing; (4) lumbering, and (5) gathering. Most settlements depend on two or more types but one is usually dominant.

Corn has evidently been the most important food crop throughout the region since settlement. It occupies more than half of the cropped land, and before the advent of wheat farming on an extensive scale, it probably included more than three-fourths of all cultivated acreage. Corn is grown under a variety of conditions; it is irrigated in most places, but in the northern part of the region as well as the higher basins, only a small part is irrigated. It is also grown in some of the more arid basins by dry farming methods, with a high incidence of crop failure. Even under optimum conditions yields are low, rarely more than 10 bushels to the acre. Small plots, usually less than 10 acres, are plowed with oxen, planted by hand and hoe, cultivated with oxen and harvested by hand. Planting time is from February to August; harvest from July to December, so that in late summer one may see corn in all stages of growth. Wheat is sometimes grown on the corn land in the winter, a fact which accounts in part for the late planting of some cornfields. Crop growth is comparatively slow, so that if two crops are grown on the same land in one year, corn is planted in August, harvested in November; wheat is planted in early December and harvested in July. Deciduous fruits, especially apples, pears, and quince, important in some localities, are commonly grown in the cornfields. Many minor crops, such as beans, *chiles, tunas,* tobacco, potatoes and many kinds of vegetables are usually grown in gardens rather than the larger fields.

Commercial wheat farming invaded the region about a generation ago. New seed was introduced from the United States, together with plows better suited to break the heavy sod of the hitherto uncultivated basins.

Harvesting and threshing machinery was also introduced and, in some of the basins with moderate rainfall, wheat became a successful crop. Yields are low, averaging about 5 bushels to the acre; rust and difficult transportation are additional handicaps. From Lirios and vicinity wheat goes to Saltillo and Monterrey, from the basins east of Cerro Potosí it goes to Galeana, Linares and Monterrey; and from the vicinity of Pablillo it moves west to the railroad. The distance from these districts to the railway is from 30 to 60 miles.

Grazing is distinctly less important in this region than in Mexico as a whole. The best natural pastures in the humid basins have been replaced by crops and the pastures in the foothills and in the more acid basins are less suited to cattle than to goats and burros. Revolutions have made heavy inroads on the livestock and today few settlements depend on grazing. Although the number of livestock in the region is difficult to estimate, since the regional boundaries cut across *municipio* boundaries, the following will at least give the relative importance of the various animals: 200,000 goats, 25,000 cattle, 20,000 burros, 7,000 sheep, 5,000 horses, and 1,000 mules.[9]

There are many small portable sawmills on the more heavily forested ridges producing rough lumber, mostly pine, but some quantities of oak and spruce. Production is limited by the position of the saw timber on the slopes of isolated summits, which tends to prevent large scale operations; by poor transportation; and by regulations of the federal government. Charcoal production, important near the larger cities such as Mexico, D. F., is not significant in this region. Turpentining has been attempted in many places, but with little success. Difficult terrain and lack of skilled workers have doubtless contributed to the failure.

The widespread practice of gathering includes the fibers and fruits of many plants, of which *ixtle de palma,* from the native yucca, is by far the most important. Guayule, source of rubber, was formerly significant. Many other articles are secured for local use only. *Tuna* cactus, widely cultivated, also grows wild on the foothills; the *maguey,* used in many localities for hedge rows between the cornfields as well as for the sap which is made into the alcoholic beverage, *pulque,* also grows wild. In addition the *maguey* is used for a temporary thatch when yucca is lacking. Firewood is gathered not only on the foothills and mountains but in the basins where the mesquite, both as a shrub and as a tree, is an important contributor.

TYPE AREAS

The discussion above suggests many variations in climate, land form, natural vegetation, and land use within the middle Sierra Madre Oriental.

[9] *México en Cifras, cit.,* pp. 57–63.

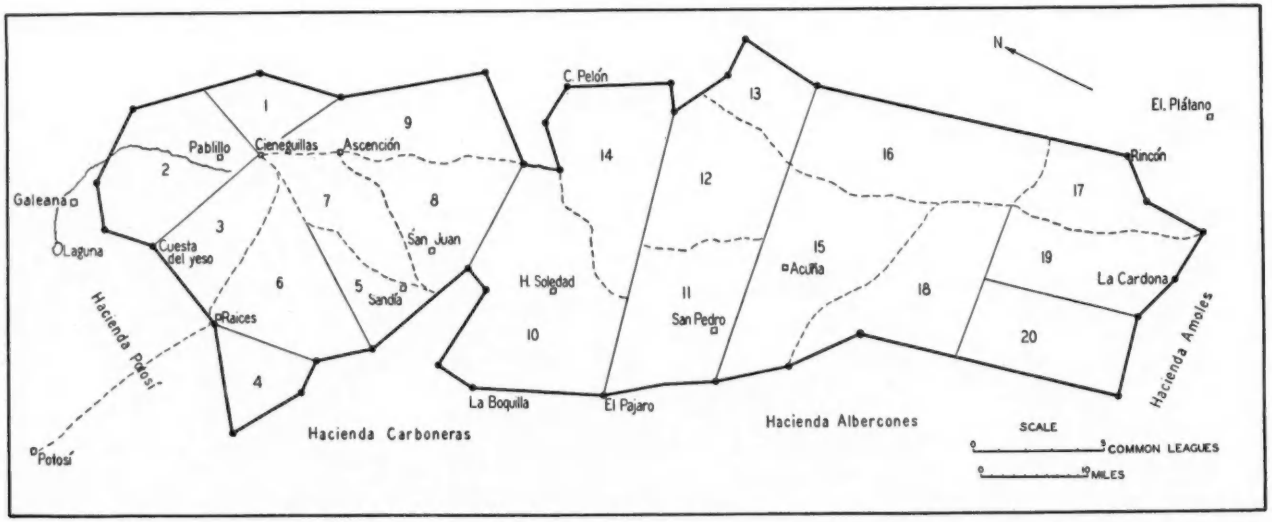

FIG. 3.—Map of the original Hacienda de Nuestra Señora de Soledad. (From a certified copy of an old map in the Secretaría de Hacienda.) The present Hacienda corresponds roughly with divisions 10 and 14 (see Figure 4).

The following studies of individual sites are scarcely typical in every respect but, together, contain most of the landscape elements found in the region. Thus, on the western side of the Hacienda Soledad (Fig. 1), exploitation of the natural vegetation is of paramount importance, since it lies on the arid margin of the middle Sierra Madre. At Pablillo agriculture is dominant with grazing and gathering secondary, and at Lirios in one of the northern valleys the climate is more favorable but there is little level land. An earlier study described the site and culture of a representative village, Galeana.[10]

SOLEDAD AND THE SOUTHERN BASINS

The settlers who entered the southern part of the middle Sierra Madre occupied parts of a large grant which included more than a million acres of mountain slope and basin land (Fig. 3). Even before the whole of the grant could be settled it was partitioned for taxes and a score of haciendas, averaging about 100 square miles, were produced. Soledad, the unit which retained the original title, lies partly in the southern end of a closed basin, 28 miles long and 10 miles wile. The westérn and southern part is fringed by low arid ranges covered with yucca, agave and cactus, but to the east the main range of the sierra rises to 12,000 feet and cuts off the eastern part of the hacienda (Fig. 4).

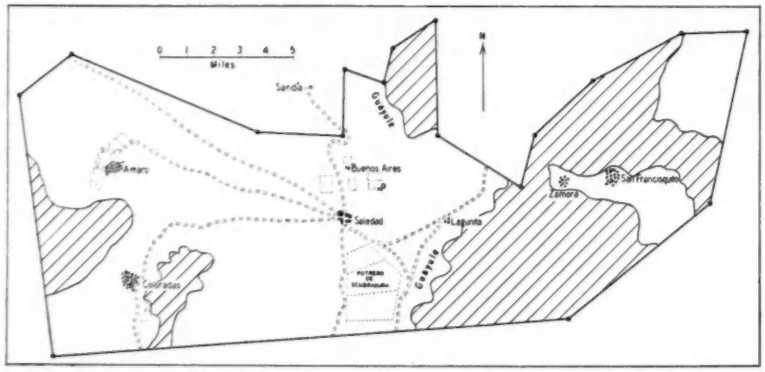

FIG. 4.—Sketch map of the present Hacienda Soledad, showing the basin land and mountain slope (latter shaded). There are nine "ranchos," seven of which are shown. Some of the cultivated fields are indicated by dotted lines. P, the pumping station (near center). Two districts, formerly producing guayule, lie next to the foothills.

[10] Dicken, S. N., Galeana; a Mexican highland community. *Jour. Geog.* **34**: 140–147, April 1935.

The broad basin slopes gently to a point south of Soledad, and in summer is sometimes occupied by a playa lake. The basin is synclinal, partly filled with alluvium. It varies in aspect: toward the middle a mesquite-bunch grass formation is most common. The mesquite reaches tree size in some localities but is usually only four or five feet high. On the borders of the basin yucca, guayule, agave and cactus are common. The most striking formation is a cedar-mesquite forest about five miles north of Soledad, (Fig. 5). Formerly many square miles in extent, this

FIG. 5.—Dry forest five miles north of Soledad. The trees are white cedar (darker) and mesquite. The cedar is used for frames of the adobe houses at Soledad.

dry forest has furnished large cedar beams for the adobe houses, including the "dormitorios" at Soledad. From the location of this forest near the foot of the eastern range, it is probable that the ground water is very near the surface in this vicinity. Although the presence of mesquite is not always a reliable indicator of shallow ground water, the wide occurrence of tree size mesquite in the eastern portion of the basin at Soledad, in locations which are never flooded, tends to confirm the evidence of the few wells that ground water is not far below the surface.

Water is obtained from shallow wells or pits, at depths of 6 to 20 feet on the eastern side of the basin. Water is pumped by steam power for irrigation and if the wells are used continuously the mineral content is fairly low, but if the water is allowed to stand in the wells for some time

it becomes very hard and unfit for use. The upper layers, at least, of the basin alluvium contain large percentages of soluble mineral, including nitrates of sodium and potassium. Although the water supply is abundant and at one time the Hacienda supported 5,000 people on its 173,000 acres, in recent years, less than 400 acres have been in cultivation. Corn is grown but not in quantities sufficient to feed the inhabitants. The population (1934) is estimated to be about 1000, which represents a very large decrease in recent years. In 1920, according to the owner, more than 2,000 workingmen lived on the Hacienda.

The principal range of the sierra is a monoclinal ridge, dipping westward. Forests of oak on the intermediate slope and pine near the crest furnish timber which is cut with a portable sawmill, hauled to Doctor Arroyo (Fig. 1) by cart and thence to Matehuala by truck. The pine forest was formerly tapped for turpentine but that has now been discontinued. The small basins to the east of the sierra are at a lower level and belong to the escarpment region.

With such varied resources activity on the land in the last few decades may be described as a series of attempts to produce and market one or more cash products. The high mineral content of the water renders cultivation of the ordinary subsistence crops, corn for example, unprofitable and except in the most favored localities emphasis has been placed on products that could be sold. And in this connection a great handicap has been the lack of cheap transportation to the nearest rail point, Matehuala. In November 1923 a contract was let to the Continental Rubber Company for the cutting and extraction of guayule. This shrub grows on the foothills marginal to the basin, reproduces itself quickly, and requires no cultivation. The price was 8 pesos ($2.20) per ton and for a time quantities of guayule were cut and the rubber extracted. With the decline of rubber prices in the world market production ceased.

Two varieties of plant fibers have been exploited in large quantities; *ixtle de lechuguilla* and *ixtle de palma*. The former is derived from a member of the agave family and yields a long strong fiber essentially the same as sisal. A small factory for the extraction of the fiber is located at Soledad and before the revolution of 1922 about 80,000 kilos of fiber were extracted monthly. The present price is low, about 12 centavos per kilo at the Hacienda. The *ixtle de palma* is harvested by the women and children from the native yucca which grows on the foothills. The leaves of the yucca are cut, tied in bundles, brought to the settlements on burros, where they are baked for 24 hours to loosen the fiber from the pulp. The fiber is combed, dried in the sun and sold at about 10 centavos per kilogram.

Agriculture has never played a large part in the life of the Hacienda aside from the subsistence crops of corn and beans. Wheat has been produced as a commercial crop but usually in relatively small quantities. Grazing, important before the revolution, is now of little significance; of all the industries in the region it has suffered most from the revolutions and the herds, almost wiped out, are difficult to restore.

HACIENDA PABLILLO

The hundred square miles of the Hacienda Pablillo bestride the main range of the sierra in the southeastern part of Municipio Galeana (Fig. 1). The eastern edge of the hacienda reaches part way down the eastern escarpment and receives heavy rains; the western part with its low treeless ranges and yucca covered basins has all the aspects of the desert margin. The greater part of the cultivated land occupies several basins to the west of the principal range in the most humid location in which basin land is to be found (Fig. 6 and inset). These basins are part of a larger basin closed to exterior drainage, except through underground channels. From the pueblo one is distinctly aware of the circle of enclosing hills and mountains, highest to the south and east, affording easy exits to the north along lines of former surface drainage. Three landscapes are clearly seen (two being shown in Figure 7). The mountain ridges, which half surround the basins to the south, lift their forested and brush covered slopes 4,000 feet above the basins, culminate in the peaks San Francisco and Infernillo, the latter about 10,500 feet above the sea. The foothills are, in part, merely the lower slopes of the mountains; others rise a few hundred feet above the basins to independent summits. Most of the basin floors are formed by the coalescing alluvial fans from the foothills but in many places the gentle slopes have been modified by solution. Limestone underlies all three landscapes, the compact gray limestone which pervades the whole region and reveals itself in many ways: in the outcrops, the solution features, the soils, and the springs. Descriptions of each of these landscapes follow.

The Mountains.—The main range of the middle Sierra Madre trends north and south through the Hacienda Pablillo. Although it is broken by passes at several points the approaches are so steep that they offer rather poor outlets in that direction. These low points in the range, however, do afford inlets for the rainbearing winds from the east. There is a strong rain shadow effect but the passes definitely diminish it. The principal peaks on the range, San Francisco and Infernillo, are merely the highest points of long strike ridges, with very steep escarpments to the east and

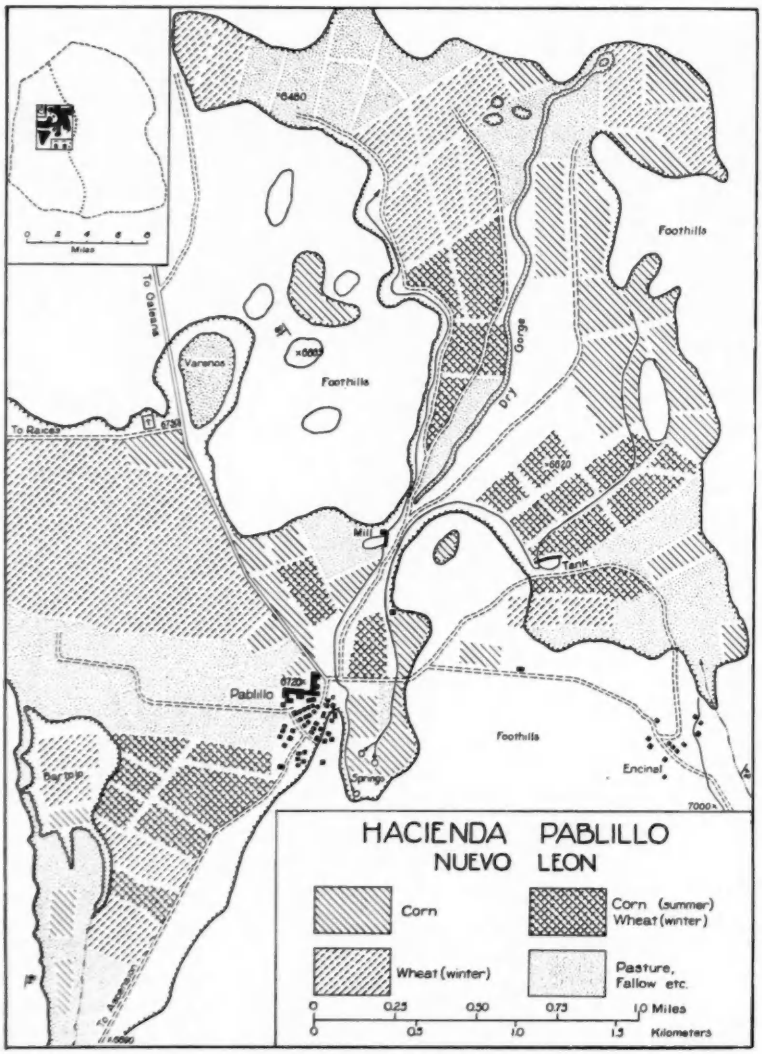

FIG. 6.—Sketch map of the Hacienda Pablillo, showing the principal cultivated basins and irrigation ditches. The inset map shows the approximate boundary of the Hacienda (exact boundary unknown to owner), also the position of the crest (dotted line) of the easternmost range of the sierra which trends slightly west of north. Unlike the Hacienda Soledad, Pablillo has only two small "ranchos" outside the dominant nucleus.

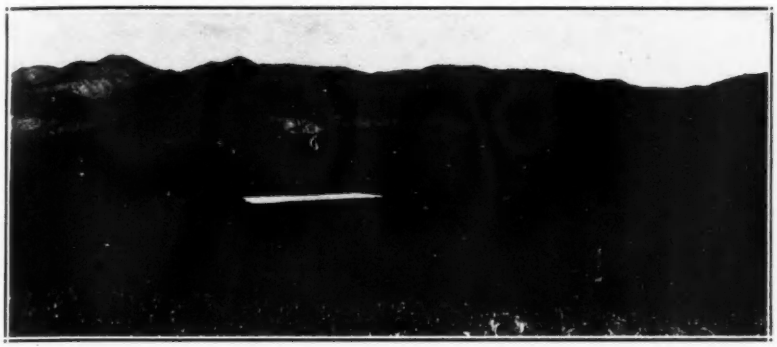

FIG. 7.—The eastern basin at Pablillo looking north from a point midway between Pablillo and Encinal (Fig. 6). Corn in the foreground and in the basin. Storage tank for irrigation in the middle distance.

scarcely less steep dip slopes to the west. The range probably represents a long overthrust from the west. It is sufficient here to note that the structure is monoclinal and that one very important result of this structure is to bring ground water from the humid summits and eastern slope to the basins at Pablillo. In spite of the heavy rainfall these mountains have little run-off. On the other hand there are numerous solution forms, small basins on the summits or, more commonly, sink holes in the shallow gorges, which absorb most of the precipitation. The mountain vegetation varies widely with exposure. The most common formation on the lower humid slope is an open liveoak-pine forest, with coarse grasses between the trees. On the more arid western lower slopes brush or chaparral is common, a mixture of oak, juniper and other woody shrubs. Large areas of yellow pine in nearly pure stands cover the upper slopes to the summits. A few meadows, which, like part of the chaparral areas, are probably culturally induced, are found on the lower slopes.

The Foothills.—The lower slopes of the mountains and the low adjoining hills are very similar in quality. Together they form a ring encircling the basins (Figs. 6 and 7). Except for some cliffs the slopes are less steep than the mountains and parts are cultivated. In the vicinity of Encinal there is a characteristic development of the foothills as to quality and use. From the bottom of the steep mountain slope at about 7100 feet, there is a sharp change in grade. The gentler slope of the foothills is not alluvial; limestone outcrops are frequent and the soil is red and thin. The oak-pine forest occupies the upper part of this slope but the lower portion has grass, some patches of chaparral, with scattered pine trees in the grass

land and some cactus (tuna). Many of the trees have been planted and are not usual in the foothills. In general the foothills are about equally divided between grass and brush. Here and there small patches of corn are grown in the most favorable locations without irrigation, particularly in the solution depressions. The principal use of the foothills is as pasture for cattle, sheep, burros, and goats. A long winding fence separates the cultivated basin land from the foothills.

The Basins.—The nucleus of Hacienda Pablillo is two large, irregular basins (Fig. 6) with a narrow connection between them. Springs supply enough water to irrigate part of the basin floors and it is here that most of the corn and wheat is grown, the latter in part without irrigation. But for these basins and springs the hacienda would probably be dependent on ranching or gathering for its livelihood.

Each basin formerly had an independent surface outlet to the north, but since the beginning of the drier climatic period, probably at the close of the Pleistocene, the rain from the entire watershed seeps through the soils to the underground channels. Except for irrigation, running water in the basins is rare. In 1910, however, due to exceptionally heavy rains, the large solution depression known as Bartolo filled with water, partly upwelling from below, and overflowed to the eastward. The discharge entered the gorge in the eastern basin and finally disappeared in the large sink-hole in the edge of the hills (Fig. 6). That this has occurred many times is indicated by the depth of the gorge, about 85 feet.

The springs which supply most of the water of the hacienda are in a re-entrant of the western basin, near the pueblo. The largest flows from an open channel at the base of a steep mountain slope; other springs in the vicinity appear as seeps in the floor of the basin and produce small ponds and a limited area of swamp. The water from all these springs is led northward in ditches, the larger passing near the pueblo to supply water for 500 people and several hundred head of livestock. A half mile to the north the main ditch enters the mill pond which serves as a tank to hold water in reserve for irrigation and to supply water for the boiler of the mill. The ditch continues northward to irrigate the northwestern part of the eastern basin. The large ditch can also be diverted into the smaller eastern ditch and thus be used to irrigate the southern end of the eastern basin, where there is another tank for storage (Fig. 7). The largest part of the western basin is without irrigation because of altitude and dry farmed wheat occupies half of the area, pasture and the corn-wheat combination accounting for the rest. Likewise there are many margins of the basin which are too high and cannot be readily irrigated, but about as much land is irrigated as the water supply will allow.

The alluvium of the basins, derived from the adjacent slopes, has been subject to weathering since deposition. The residual soils of the mountain slopes are gray to black in the upper or "A" horizon, dull to brick red in the underlying "B" horizon, as is characteristic of soils developed from limestone in a humid region. Both soil and subsoil from the foothills and mountains have contributed to the alluvium of the basins. Even today when the mountain canyons contain water during rains there is a heavy load of reddish sediment. The "A" layer of soil in the basins is gray to black. Before cultivation the dominant vegetation in the basins was grass and conditions for soil development were those of the moist margin of the steppe. A well drilled at Pablillo logged 6 feet of black soil, derived partly from the foothills, and 65 feet of red earth to limestone and water. The gorge in the eastern basin is intrenched 85 feet in the alluvium without showing bed rock. At various points along the bottom of the gorge solution depressions occur which usually absorb any water which runs in. From the rim of the gorge the land slopes away gently to the adjacent basins, giving the effect of a distinct natural levee.

A half century ago only a small part of the basins was in cultivation. The heavy sod resisted the crude plows of the peons, but with the introduction of modern plows from the United States the sod was broken and since that time plowing, with oxen and ordinary plows, has been comparatively easy. The basin land is divided into four major parts, each with some distinctive qualities of its own. The upper part of the western basin is northwest of the village (Fig. 6), cannot be irrigated and is limited to winter wheat and a few patches of unirrigated corn. All of the southern part of the western basin, southwest of the village, can be irrigated, including the solution depression Bartolo which lies about 40 feet below the general level. Most of the land is divided into small plots which are alternately, winter and summer, planted with wheat and corn. On smaller patches (not shown in Figure 6) there is some cultivation of beans, *chiles* and various other vegetables. The eastern basin is divided into two parts by the dry gorge and the slightly elevated land bordering it. The northwestern part, west of the gorge, is drier and has a larger amount of fallow land. The southeastern part, immediately north of Encinal, lies partly on a large alluvial fan and is decidedly gravelly in texture. Varying conditions within the basins, such as the above, are accompanied by widely differing yields: wheat yields up to 9 bushels to the acre, the average being about 6; the yield of corn is only slightly higher. General crop failures are rare, but failure on individual plots are common. Light rainfall and rust are contributing factors to the low wheat yields; cool summers limit the yield of corn.

By no means all the activity of the hacienda is agricultural. There are about 300 head of cattle (compared with 3,000 fifteen years ago), 50 oxen, more than 100 horses, 50 burros, and 100 head of goats. The foothills contain most of the grazing land but pasture grades from the unused portion of the basins, where the animals are carefully herded from the unfenced crops, to the tops of the highest mountains. The gathering and preparation of *ixtle* from the yucca which grows abundantly on the western edge of the hacienda, provides many of the peons with a small money income. Turpentining, though not practiced at present, has been attempted at various times. There is little lumbering probably because of the difficulty of transportation.

Most of the 500 people on the Hacienda Pablillo live in one compact settlement (Fig. 8). The peons live in small adobe houses with yucca

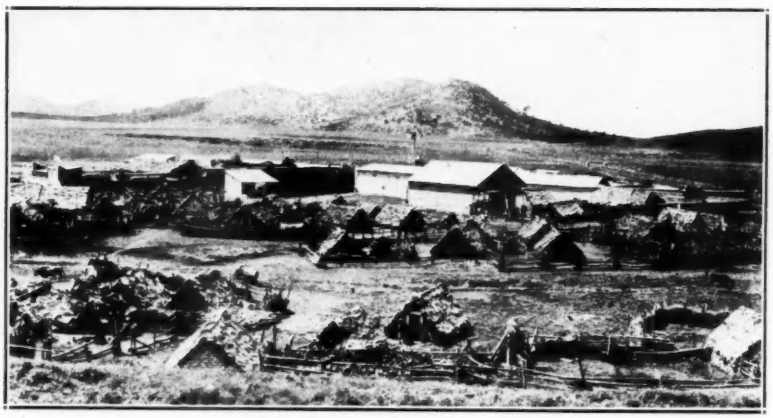

FIG. 8.—The pueblo at Hacienda Pablillo, looking north. The houses are adobe with yucca thatch, except that the larger buildings, homes of the owners, have metal roofs.

thatch roofs. There are no chimneys, the smoke from the cooking fires filtering up through the roofs. Around the houses there are numerous corrals in which the personally owned livestock—horses, cows, burros—of the peons are quartered. The houses of the owners are larger single story structures, with metal roofs and cement floors. The larger buildings include a store, school and warehouse for storing grain, ixtle, etc.

CERRO POTOSÍ

Cerro Potosí, the highest point in a long strike ridge, rises 6,000 feet

above the adjacent basins to an elevation of about 12,000 feet. In summer the crest is usually obscured by cloud, and rains are of almost daily occurrence on its higher slopes (Fig. 9). On the eastern side, the forest of spruce and pine ranges from about 7,000 feet to the summit. In spite of the

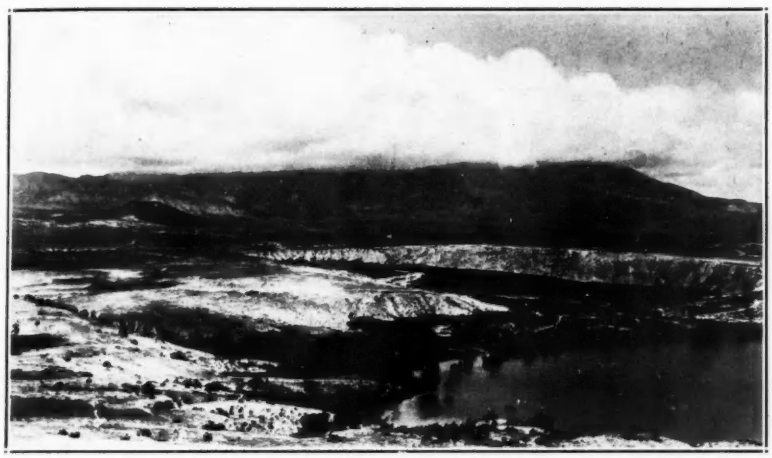

FIG. 9.—View of cloud-crested Cerro Potosí from Laguna, near Galeana. The cloud, accompanied by rain on the mountain but not in the basin, is typical of a summer midday. The broad basin at the foot of the mountain produces much wheat but has little water for irrigation. In the foreground the spring-fed lake, Laguna, which occupies part of a large solution depression, supplies Galeana with water for irrigation. Note the smaller solution basins on the left.

frequent rains, there is little evidence of running water; apparently a very large proportion of the rain water enters underground channels and since the ridge lies mostly on the west arm of an anticline, the ground water finds its way readily to the arid western slope and appears in several large springs. At the largest spring is the Hacienda Potosí with a population of about 1500, whereas the largest settlement on the east slope is the Hacienda San Francisco with only 250 people. Although more land is cultivated on the eastern side of the mountain, where the rainfall is sufficient for wheat without irrigation, the settlements are small. Many of them are of recent origin and are occupied only in December at planting time and in July at harvest, the owners living in Galeana or even Monterrey. Small settlements are also found in some of the solution basins on the slopes of Potosí and in the saddles of the main ridge. Corn and wheat are grown up to 9000 feet. The floors of high basins which are too moist for cultivation are

in pasture and the crops are grown on the marginal slopes, a reversal of conditions in the lower basins.

LIRIOS

Northward from Galeana the ridges and valleys have a westward trend and in the vicinity of Saltillo, the ranges strike almost due west (Fig. 2). The valleys are usually narrow, affording little land for cultivation; they are more open to the east, allowing the rain-bearing winds to enter. Not only is surface water more common, but because of the limited amount of arable land it is perhaps of even greater relative significance. There are also numerous springs; a few are used for irrigation, others merely for household water supply.

FIG. 10.—The Upper Valley at Lirios, looking westward down the valley. The floor of the valley and parts of the bordering alluvial fans are in corn, wheat and fallow, the steeper slopes in forest and brush.

Typical of the northern region in general is the upper settlement at Lirios (Fig. 10) about 50 miles east of Saltillo. Upper Lirios lies in a narrow east-west valley cut in a steeply dipping anticline. The steep bordering ridges rise 2000 feet above the valley floor, to an elevation of 10,000 feet. The valley contains a small perennial stream, running along the south side, whereas the largest alluvial apron is on the north side, a circumstance unfavorable for irrigation. Corn and wheat are grown on the comparatively steep fans without irrigation. Here and there a few terraces have been constructed to check soil erosion, a condition almost unknown in

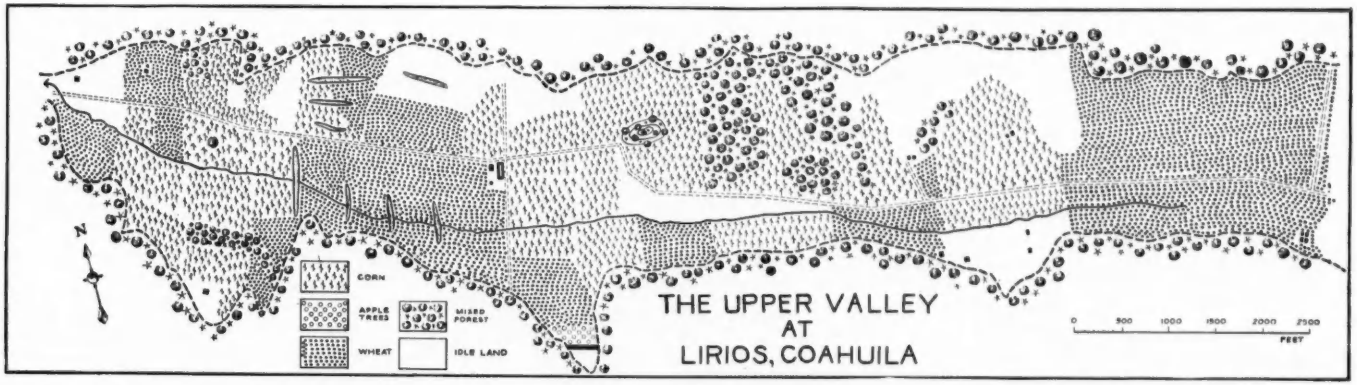

FIG. 11.—Sketch map of the upper valley at Lirios, Coahuila. Note the small embankments constructed across the stream and on the slopes (above the legend) to check soil erosion.

the southern part of the region. The valley profile shows some contrasts in vegetation: on the north side the zone of thin timber extends from 8200–8700 feet, above that chaparral thins rapidly to a rocky summit. The southern slope is more humid, with mixed oaks and pines on the lower slopes, mixed conifers on the upper slope. There is a sawmill on the southern slope, many other mills in the vicinity. The most striking feature of the valley floor is the position of the stream at the southern margin of the valley and the long colluvial slope from the north side. This means that most of the cultivated land is on the north side of the stream (Fig. 11). Cultivation is about equally divided between wheat and corn but in the winter season wheat is grown on some of the corn land. Most of the forest land in the floor of the valley is steep or rough. The most important cash products are wheat and lumber.

FUTURE OF THE SIERRA MADRE ORIENTAL

The Middle Sierra Madre produces a surplus of certain articles, such as wheat, deciduous fruits, *ixtle*, and lumber which should find a market in adjacent regions. It is also evident that if the market for these items becomes more accessible, production in the region can be greatly increased. The key to the future, therefore, lies largely in improved communication. The most logical exchange of products is with the piedmont region and particularly Monterrey. The importance of Galeana at the head of the least inaccessible canyon leading to the piedmont reflects the urge to exchange the products of the mountain basins for the subtropical crops such as sugar, citrus fruits and bananas which grow in the lower altitudes. A similar exchange is made farther north via Saltillo to Monterrey. South of Galeana the canyons leading to the piedmont are so difficult, even for pack animals, that most of the trade in the southern part of the region goes directly or indirectly to Doctor Arroyo and Matehuala, and thence by rail to San Luis Potosí and Mexico, D. F.

Although there is no railroad in the region and not more than 50 miles of graded road, local trade is not thereby greatly handicapped, except for short periods in summer due to heavy rains. Much traffic is still carried by burro and oxcart, but trucks are being used on some of the easier routes. Roads are now under construction which will reach all the important producing districts. Galeana will be connected with Doctor Arroyo, Linares and Saltillo, and many branch roads are planned. The route from Linares to Galeana presents the greatest difficulty because of the narrow canyon and heavy rainfall on the escarpment. Once good roads are available the economy of the region will undoubtedly change. Production of wheat, fruit, lumber and other crops will increase and the region will begin to overcome, in part at least, its two century old handicap of isolation.

University of Minnesota,
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